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Paleoenvironmental Reconstructions and Organic Matter Characterizations of Peats and Associated Sediments From Cores in a Portion of the Lafourche Delta (Foraminifera, Maceral Analysis, Gemmules, Louisiana).

Scott Warren Beckman
Louisiana State University and Agricultural & Mechanical College

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PALEOENVIRONMENTAL RECONSTRUCTIONS AND ORGANIC MATTER CHARACTERIZATIONS OF PEATS AND ASSOCIATED SEDIMENTS FROM CORES IN A PORTION OF THE LAFOURCHE DELTA

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PALEOENVIRONMENTAL RECONSTRUCTIONS AND ORGANIC MATTER CHARACTERIZATIONS OF PEATS AND ASSOCIATED SEDIMENTS FROM CORES IN A PORTION OF THE LAFOURCHE DELTA

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Marine Sciences

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ABSTRACT

This study of peats and associated sediments from a portion of the Lafourche delta had four objectives: (1) to develop methods for reconstructing paleoenvironments of buried peats and their associated sediments from core material; (2) to apply these paleoenvironmental methods to reconstructing the history of sedimentation; (3) determine the relationships between peat formation and deltaic environmental conditions; and (4) to reconstruct the development of an interdistributary basin during the Lafourche deltaic episode.

Three cores and several auger derived samples were recovered from a portion of the Lafourche delta, southeast Louisiana. Paleovegetation analysis of the cores was accomplished by comparing the seed assemblages of the buried peats to the modern-day floral community structures (marsh types) of the coastal Louisiana peat-forming environments. Since salinity is the most important floral ecological regulator in the coastal Louisiana marshlands, paleosalinity indicators were developed utilizing marsh and estuarine foraminifera (mesohaline indicators), and gemmules (oligohaline indicators). Chemical paleosalinity indicators were also tested.

The important conclusions of the study are outlined below:

(1) Analyses of the three study cores revealed progressive increases in salinity from the bottom of each core to the top. Coincident with these salinity increases were changes in marsh types from fresh marshes towards the base of the cores, to intermediate and brackish marshes in the middle of the cores, and saline marshes at the surface.

(2) The duration and magnitude of salinity variations through time were the most important factors controlling the occurrence and organic matter content of the intermediate and brackish marsh deposits.

(3) Results of the maceral analyses from the cores revealed mechanisms of organic matter sedimentation, and elucidated environmental conditions during deposition and early diagenesis.

(4) The chemical paleosalinity indicators tested were unsatisfactory due to the vertical migration of fluids from the surface sediments.

(5) A reconstruction of interdistributary basin formation was developed utilizing results from the paleoenvironmental core data and auger sediment descriptions.

(6) A peat classification system, based on the results from this study, was designed to integrate descriptions of peat floral composition with salinity and measurements of organic matter type.

I. GENERAL INTRODUCTION

The goal of this study was to reconstruct the evolution and mechanisms of peat formation from core material deposited in a deltaic setting. The reconstructions include an assessment of the effects of changing environmental factors on the type and quality of the peat and associated sedimentary environments.

A specific study area was chosen containing peats and associated sediments deposited in an interdistributary basin located between two minor secondary channels in the lower portion of the Lafourche delta. The interdistributary basin examined in this study is a small scale lower deltaic feature representing basin fill of a crevasse splay. The usage of the term "interdistributary basin" in this study is not to be confused with the larger interdistributary basins that occur between meander belts of the upper deltaic plain.

The interdistributary basin examined in this study contained a complete and shallow sequence of an interdistributary basin fill. The short sedimentary sequences (3 meters) and small areal extent of the basin (5 km wide) facilitated the reconstruction of deltaic peat formation.

Peat is a highly organic sediment deposited in a unique sedimentary environment. The accumulation and accretion of peat deposits are dependent on a balance between biotic factors and sedimentary processes. Furthermore, the environmental factors controlling peat formation in a deltaic setting are highly variable over geologically short time periods.

The modern paralic peat-forming environments of coastal Louisiana have primarily been studied from the standpoint of modern plant community structure, marsh typology, and chemistry (Penfound and Hathaway, 1938; Russell, 1942; Brown, 1948; O'Neill, 1949; Eggler, 1961; Palmisano, 1970; Palmisano and Chabreck, 1972; Chabreck, 1972; Shiflet, 1963; Chabreck and Condrey, 1979). However, no study has focused on the long term temporal relationships among plant community structure, environmental factors, and the resultant organic nature of the coastal Louisiana peats.

The classical means of understanding peat formation and accretion involves time-specific studies of changes in the plant community structure and its influence on the type and rate of peat deposition. The major drawback is the short time intervals studied, resulting in an inability to observe significant changes in peat type. Furthermore, man induced changes to the wetland environment may alter the

natural processes of peat formation. The most profound modifications have been the construction of levees, dams, and canals, as well as the introduction of exotic floral species such as the water hyacinth.

An alternate approach in peat formation studies utilizes buried peats and associated sediments from core material as a means of reconstructing past environments of deposition. This approach allows the investigator to detect continuous changes in peat type over long periods of time. The success of paleoreconstruction methods is highly dependent on the careful choice of paleoenvironmental indicators.

To accomplish the stated objectives, it was first necessary to develop methodologies for identifying paleoenvironments of deltaic sediments. Considerations included developing paleovegetation indicators, as well as indicators of the important factors governing marsh type. The environment of deposition also controls the "quality" of the organic matter in the peat. Thus measurements of organic matter "quality" comprise an important aspect of this study. Organic matter "quality" is defined here as the combination of factors relating organic matter quantity, type, and degradation state to a particular sedimentary environment.

This study focuses on the historical development of sediments from three continuous cores recovered from deposits of the Lafourche deltaic system. The Lafourche delta was an ancient Mississippi River drainage system that deposited a lobe of sediments between 600 and 1900 years B.P. (Frazier, 1967). The relationship between core locations and the physiographic deltaic environment was deduced from auger tests and paleodistributary reconstructions of relict stream channels.

Detailed paleoenvironmental reconstructions compiled from the fossil analyses, organic matter characterizations, and auger data were integrated and used to develop a detailed history of interdistributary basin formation during the Lafourche delta. In addition, processes of marsh formation and the mechanisms of organic matter accumulation were developed. The fossil reconstructions provided the framework for studying several chemical paleosalinity indicators. Finally, a peat classification system was developed. The system will aid future peat studies by developing a process oriented classification based on vegetation type, organic matter quality, and environmental factors.

Since this study involves several disciplines in the fields of paleontology, chemistry, and organic petrography, the background information for each technique will be

presented before each section of results. This approach enables a comprehensive understanding of the technique to be evaluated relative to the paleoenvironmental indicator.

II. BACKGROUND INFORMATION

Deltaic processes and environments of peat formation

The peat-forming environments of coastal Louisiana consist of extensive paralic marsh and swamp wetlands. Natural marshes alone occupy about two and one-half million acres, or approximately one-third of the total Louisiana coastal region (Chabreck, 1972). The characteristics and quality of a peat deposit are dependent on the interactions between the floral community and dynamic environmental conditions.

Peat formation in coastal Louisiana is integrally coupled to the process of deltaic sedimentation. Recent deltaic sediments of the Mississippi River were deposited during the last few thousand years of post-glacial time (Fisk, 1955). The 200-mile-wide deltaic plain of the Mississippi River was constructed over the past 6,000 years. Delta lobes (progradations of the river) are characterized by cyclical events of aggradation, followed by depocenter shifting in response to decreasing river gradients. Frazier (1967) recognized four major delta complexes: the Teche, St. Bernard, Lafourche, and Plaquemines-Modern. Several delta lobes comprise each complex as depicted in Figure 1.

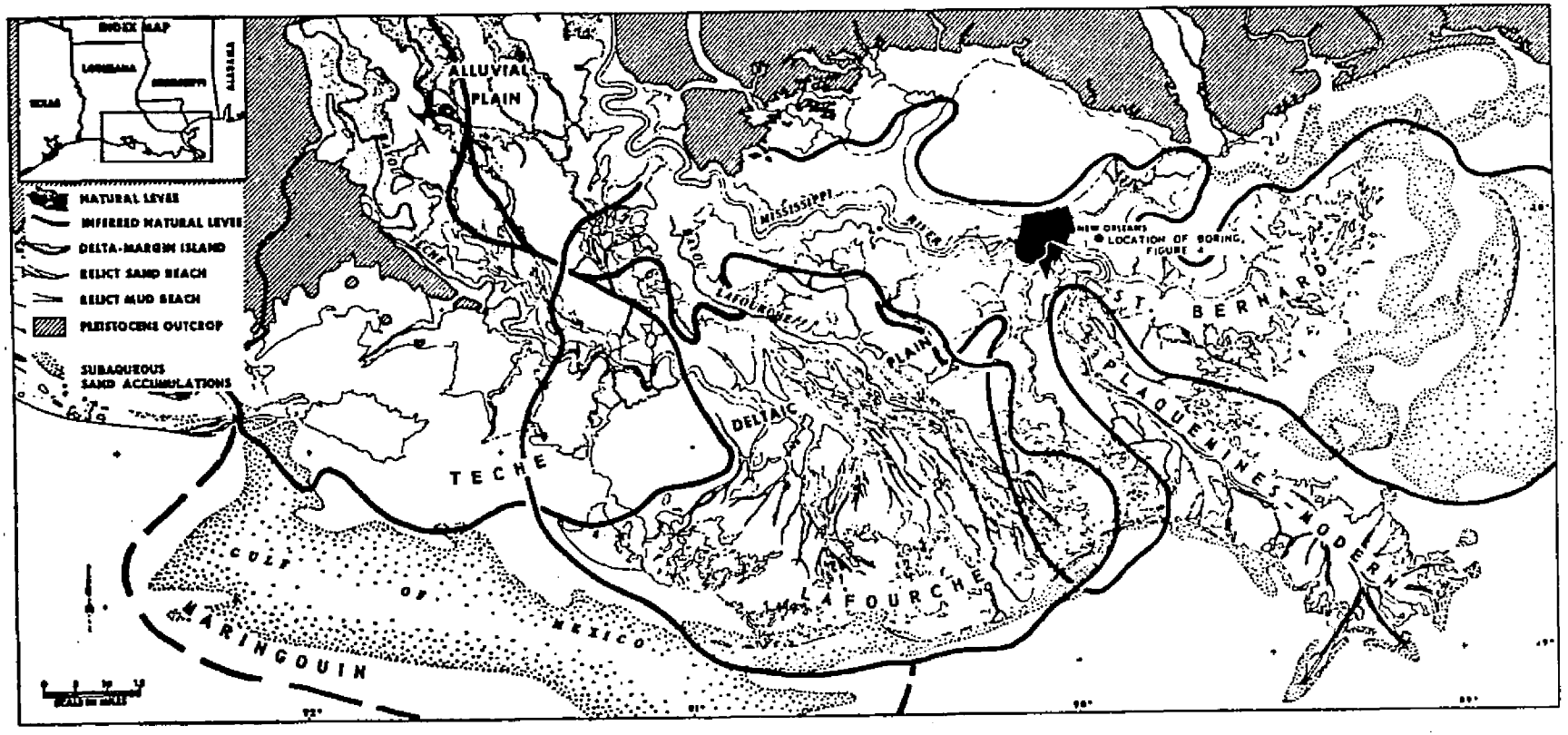


FIGURE 1. Delta Complexes of the Mississippi Delta Plain (Frazier 1967)

The development of a delta lobe, the facies relationships, and associated peat-forming environments of the Mississippi delta are well documented (Fisk et al., 1954; Welder, 1959; Kolb and Van Lopik, 1966; Frazier, 1967; Frazier and Osanik, 1969; Coleman and Gagliano, 1964; Coleman and Gagliano, 1965; Coleman, 1966; and Gould, 1970).

A deltaic sequence is initiated by the deposition of riverborne sediments onto the continental shelf. Finer sediments are carried and deposited as prodelta silty clays. As progradation continues (and water depth decreases), delta front silty sands are deposited over the prodelta sediments. A lenticular silty-sand distributary mouth bar is deposited in front of the main channel as the distributary progressively builds seaward. Bifurcation of the main distributary occurs when it is unable to cut a channel through the bar sands. An interdistributary bay is thus formed, receiving fine grained detritals as levee overbank deposits during floods. Lenticular peat deposits form in these interdistributary bays when infilling decreases water depth allowing vegetation to flourish. Inevitable abandonment of the distributary, due to a loss of gradient, results in the transgression and erosion of distal deltaic facies. Reoccupation of an old distributary may occur at a future time, reinitiating the delta cycle.

Fisk (1955) described the development of typical interdistributary peat deposits. Several peat types occur during the evolution of the interdistributary basin in response to changing geological and ecological conditions (Figure 2). The first deposits to accumulate in the basin are highly organic mucks. The first true peats accumulate in fresh-water marshes adjacent to the natural levee. As the interdistributary bay fills, slightly brackish marsh peats accumulate in the central portion of the basin. With time, gradual deterioration of the distributary system results in the reduction of fresh-water input to the central basin. Brackish marsh peats form in the central basin while swamps succeed the fresh marshes adjacent to the natural levees. Total abandonment and subsidence allows sea water to intrude, resulting in deposition of saline marshes and bay deposits.

Coleman and Gagliano (1964) defined the detrital component (interdistributary facies) as part of the active or progradational phase of delta construction. Marginal deltaic environments bound the active delta, depositing an extensive blanket of carbonaceous sediments. The interdistributary peat deposits are characterized by abrupt facies changes and rapid sedimentation rates. Conversely, marginal deltaic peats are laterally extensive, fine grained, and exhibit slower deposition rates.

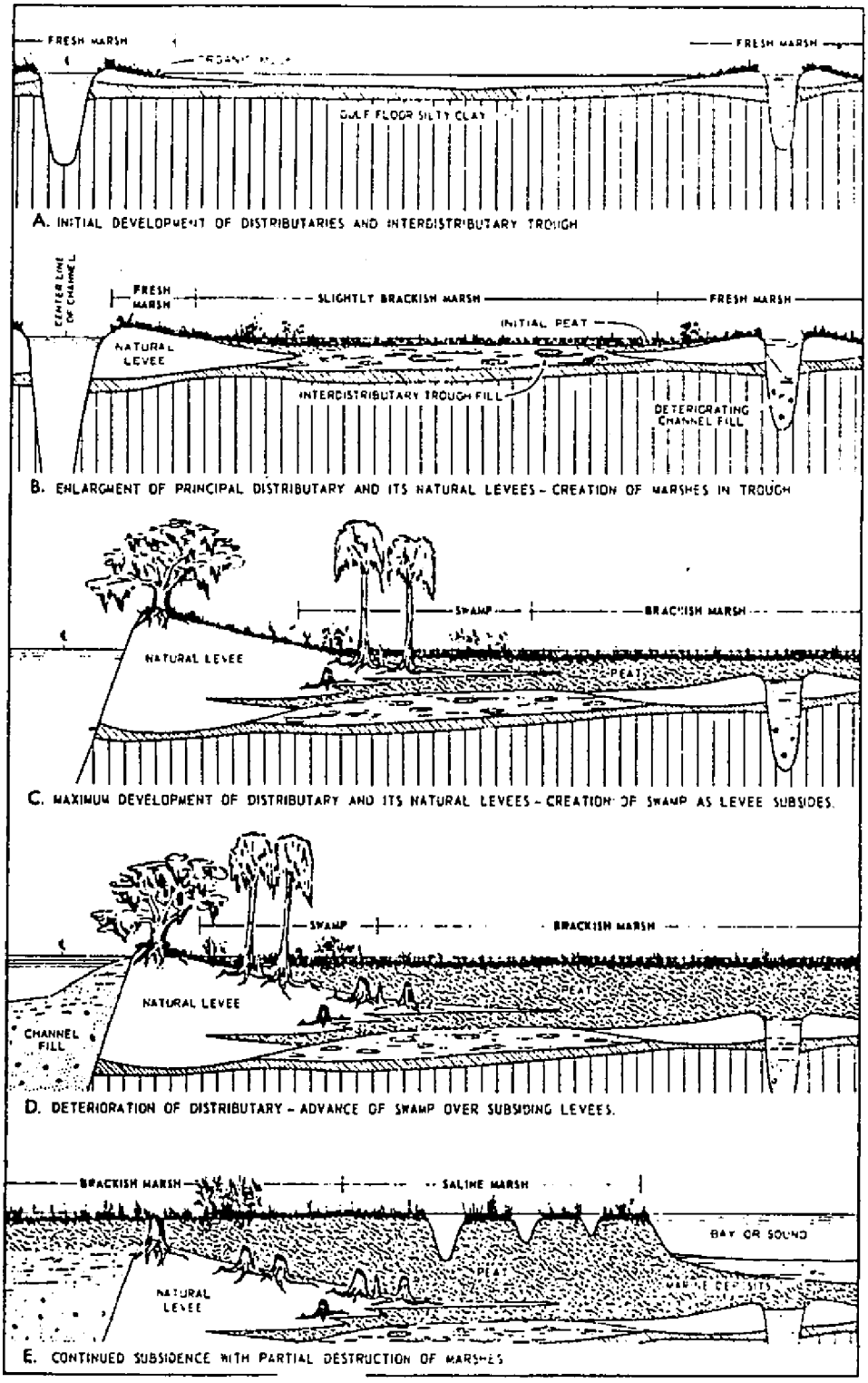


FIGURE 2. Interdistributary Peat Deposits (Fisk 1955)

Marsh types of coastal Louisiana

In order to reconstruct ancient marsh types and deduce paleoenvironmental conditions from a peat sequence, it is essential to understand the present-day floral community structures and their environmental regulators.

Floral zonation in peat-forming environments of the Louisiana coast is primarily controlled by: (1) the salinity of the marsh soil, and (2) water depth. Penfound and Hathaway (1938) classified four marsh types (on the basis of salinity) as fresh marsh, slightly brackish marsh, brackish marsh, and saline marsh. Water depth also plays an ecological role by dictating the plant successional stage (Penfound, 1952). Succession causes a lowering of the water level as the organic sediments accrete. The successional stages proceed from a submerged community, to a floating stage, to a true marsh, and finally to a climax swamp community. Penfound also observed that the saline marsh did not possess a submerged or floating stage since the dominant species (*Spartina alterniflora*) could directly invade shallow ponds and bays.

The four marsh types roughly parallel the Louisiana coast in response to the decreasing landward salinity gradient derived from the mixing of saline tidal waters and freshwater runoff.

A quantitative study of the plant associations in each of the four marsh types was conducted by Chabreck (1972). He encountered 118 species from the marshes and numerous ponds and bays along the entire Louisiana coastline. The relationships between these plant communities and the type of organic sediment was investigated by Palmisano and Chabreck (1972). A brief review of the vegetation and organic sediments of the four marsh types follow.

Saline Marsh

The saline marsh environment contains the lowest diversity of plant species and is almost entirely dominated by *Spartina alterniflora*. *Distichlis spicata* and *Juncus roemerianus* are also encountered, but not limited to the saline marsh. Organic matter content of saline marsh soils is the lowest of the four marsh types, averaging approximately 25%. Mean water salinities average 15 ppt (Palmisano and Chabreck, 1972). The water level overlying the saline marsh is, on the average, the lowest of the four marsh types.

Brackish Marsh

The brackish marsh is florally more diverse as compared to the saline marsh. The dominant species is *Spartina patens* in association with other species such as *Eleocharis*

parvula, *Scirpus robustus*, *Scirpus olneyi*, *Juncus roemerianus*, and *Distichlis spicata*. The organic content averages approximately 35%, with surface water salinities averaging 7 ppt (Palmisano and Chabreck, 1972).

Intermediate Marsh

The intermediate marsh is a unique transitional environment containing species found in both the brackish and fresh marshes. There are no true endemic species, however, several species reach their highest abundance in this environment. Some of the more important intermediate marsh species are *Cyperus odoratus*, *Bacopa monnieri*, *Echinochola walteri*, *Leptochola fascicularis*, *Panicum virgatum*, and *Pluchea camphorata*. The organic matter content is generally higher than in the saline and brackish marshes, averaging 45%. Salinity of the overlying waters averages 3.5 ppt (Palmisano and Chabreck, 1972).

Fresh Marsh

The fresh marsh community is the most diverse of the four marsh types. Chabreck (1972) reported that of the 118 plant species encountered in his study, 92 can be found in the fresh marsh. The most abundant species, *Panicum hemitomon*, comprises approximately 25% of the fresh marsh vegetation. Organic matter content of the fresh marsh soils is the highest of the four marsh types, typically being

greater than 50%. The water overlying the fresh marsh is virtually fresh (Palmisano and Chabreck, 1972). In addition, the depth of the overlying water is the greatest of the four marsh types.

The species composition within each of the four marsh types is not strictly homogenous. Environmental factors, such as elevation, soil organic content, and nutrient levels play an important role in dictating species heterogeneity. Furthermore, the Louisiana marshes are not as sharply zoned as the tidal marshes of the Atlantic coastal province (Miller and Eggler, 1950; Adams, 1963). The low tidal range and low gradient of the Mississippi deltaic plain produce gradational marsh types, often masking a true demarcation line.

The lack of a definitive zonation, coupled with the complex species associations, complicates peat formation studies which rely on an areal and time-specific approach. A temporal approach, utilizing buried peat sequences, is a more informative method for elucidating the historical and environmental aspects of marsh formation.

Peat classification

Waksman (1930) defines peat as "a layer of the earth's crust consisting largely of organic matter, which has

originated as a result of incomplete and partial disintegration of the various constituents of the natural plant materials due to anaerobic processes under which plant decomposition has taken place." Peat deposits are end members in a series of sedimentary types, whose classification is based on the type and amount of organic matter. High concentrations of sedimentary organic matter can only be achieved by deposition in an environment of high productivity and predominantly reducing conditions. These criteria are met in environments such as bogs, swamps, marshes, and certain limnic sediments.

The classification of a peat has classically been based on two criteria: (1) the plant community assemblage, and (2) the degree of decomposition of the organic matter. An excellent review of peat classification is presented by Farnham (1963) and outlined in Figure 3. The type of plant community structure is classified on the basis of botanical composition (Sphagnum, Hypnum, Herbaceous, or Woody). The degree of decomposition is assigned by a macroscopic evaluation. Fibric peats consist of unaltered, recognizable plant fragments. Mesic peats are semi-fibrous and partially decomposed. Sapric peats are highly decomposed, containing little or no recognizable plant fragments.

This classification scheme is adequate for a field description of peat type. A more sophisticated system is

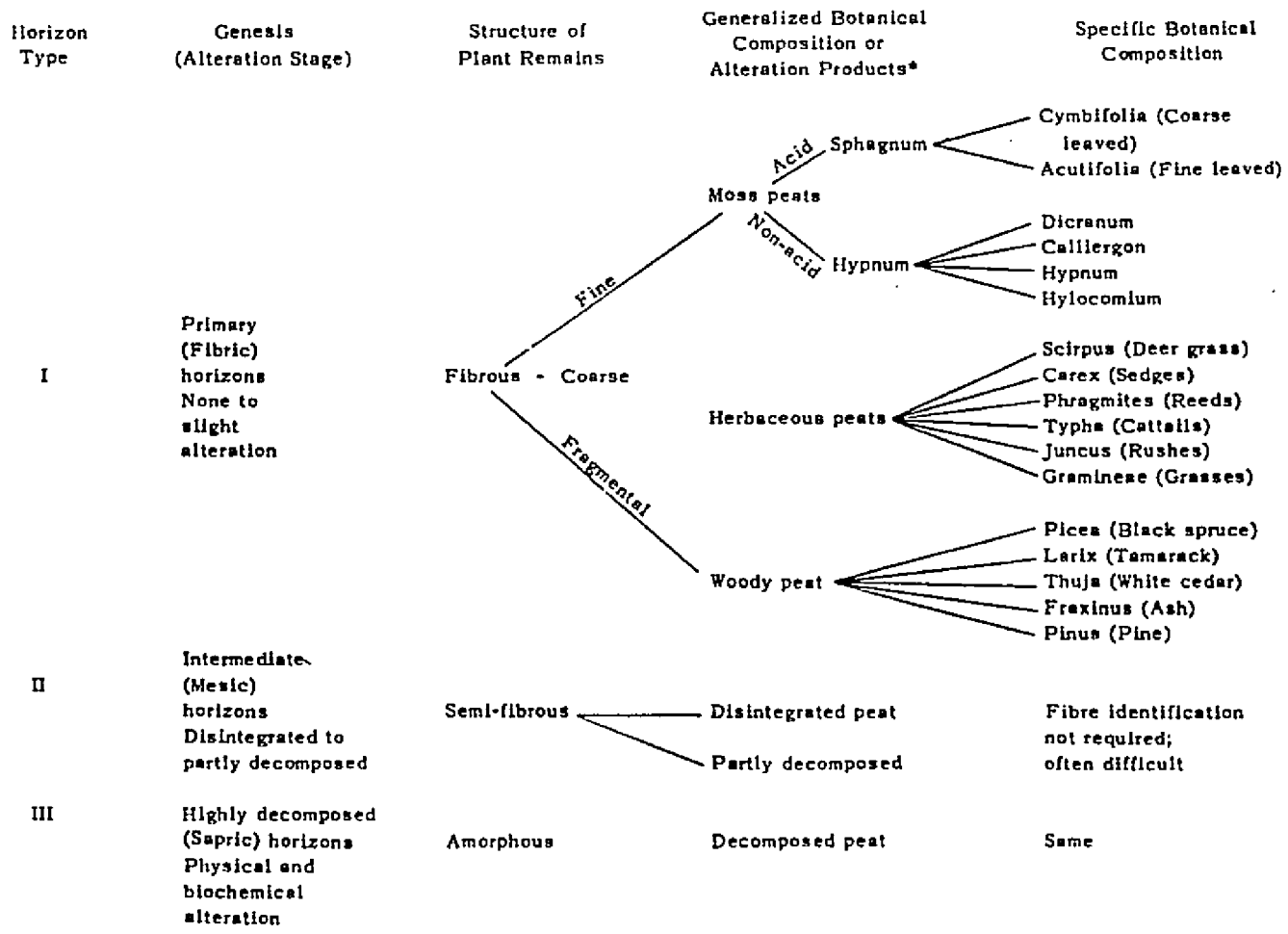


FIGURE 3. A Peat Classification System (Farnham 1963)

necessary for the complete characterization of recent and buried peats.

Peat reconstruction

The most comprehensive studies of peat reconstructions have been assembled by Spackman and his co-workers. (Spackman et al., 1966; Cohen, 1968; Cohen, 1973; Cohen and Spackman, 1972). The modern peat forming environments were petrographically examined utilizing impregnated thin sections. Recognizable plant fragments, such as roots, leaf matter, and other plant organs, aided the classifications of the modern environments. The petrographic constituents of the ancient peats were then compared to the modern peats to determine paleoenvironment.

Cohen (1968,1973), in two separate studies of the Everglades complex and the Okefenokee complex, used the peat petrographic technique to reconstruct buried marsh and swamp environments. Beckman (unpublished) utilized thin sections of root material to reconstruct the vegetational history of a cored sequence from a Long Island tidal marsh.

Utilizing macro-organic plant fragments as vegetational indicators of ancient marshes can be applied to systems whose community structures are relatively simple and sharply zoned (as in the previous studies cited). However, the peat forming environments of coastal Louisiana are not

sharply zoned and plant community structures, for the most part, are more complex. Classification of peat typology based solely on macro-organic material cannot provide suitable resolution to characterize and quantify rapid environmental changes in the coastal Louisiana environments. Furthermore, the problem of downward migration of root and rhizome material poses a major problem.

The use of pollen analysis in reconstructing peat deposits is adequately reviewed in Cain (1939), Martin and Gray (1962), and Faegeri and Iversen (1975). Pollen analysis is most useful in studying climatically induced floral changes of thick bog deposits. The pollen assemblage of a sediment can be used to broadly determine some aspects of the environment of deposition of a sediment. Spackman et al. (1966) used pollen analysis to determine the distance from the shoreline in the Everglades-Mangrove complex.

The major shortcoming of environmental palynological analyses is the transportation by air and water of pollen grains away from the source of the floral community. The problem is more severe in deltaic environments, due to complex hydrologic processes which mix and transport pollen grains. Darrell and Hart (1970) attempted to statistically classify the modern Mississippi deltaic environments according to their pollen assemblages. The study

demonstrated a greater variance within the environment than between environments.

Therefore, pollen analysis is a valuable tool in determining climatic and floral community changes within a wide geographical area over long time periods. However, it is of limited use in detailed studies of plant community changes operative over relatively short time periods and under complex hydrologic regimes. For these reasons, pollen analyses were not undertaken as a part of this study.

III. STUDY AREA AND CORE DESCRIPTIONS

The study area was specifically chosen to investigate the interactions between dynamic deltaic processes and peat formation. The area is located in Barataria basin, southeast Louisiana, and is bounded on the west by Bayou Lafourche and on the east by Caminada Bay (Figure 4). Saline marshes, dominated by the halophyte *Spartina alterniflora*, are at present depositing a blanket peat over the area in response to the encroachment of saline water. The sediments underlying the present-day saline marshes were influenced by the Lafourche deltaic system. In 1904 Bayou Lafourche was artificially closed, thus limiting the distribution of fresh water to the adjacent marshes.

During the progradation of the Lafourche delta, several smaller secondary channels branched off from the main distributary. These secondary channels formed small-scale interdistributary environments. Sediments deposited in these basins represent a shallow historical record of events in the lower portion of the Lafourche delta.

The relict stream channels in the study area have not totally subsided beneath the saline marsh. These channels delineate the mini-interdistributary basins depicted in Figure 4. The paleodistributary reconstructions are based on examinations of aerial photographs and a published

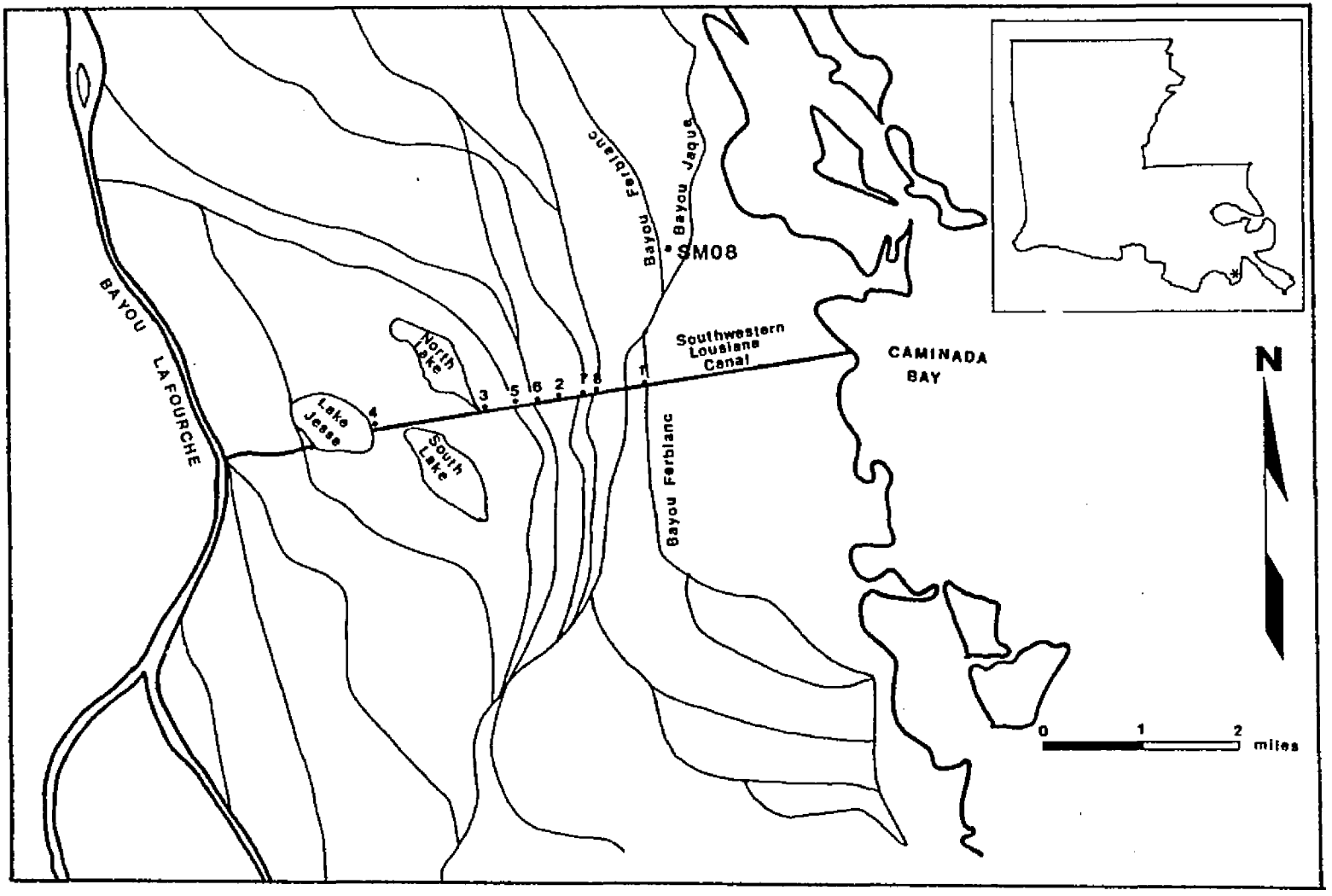


FIGURE 4. Study Area

reconstruction (Krumbein and Aberdeen, 1937). The ability to recognize these mini-interdistributary basins, in conjunction with the shallow deltaic sediments underlying the surface peats, produced a favorable study area to examine processes of peat formation in a deltaic setting.

Eight auger core tests were made on a transect along the Southwestern Louisiana Canal between Bayous Lafourche and Ferblanc (Figure 4) to determine the best sites for coring operations. A dark peat unit was present in all augers (Figure 5). This peat unit was thickest and most deeply buried in the central portion of each basin. The peat layer was thinner and less deeply buried immediately adjacent to the channels. Furthermore, the thickest peat sequences occurred within the larger interdistributary basins.

This study focused on the formation of peats and associated sediments from the largest of the interdistributary basins. This basin is located between the first and second channels east of Bayou Lafourche. Two continuous cores were recovered in the basin at sites SWLA3 and SWLA4 (Figure 4). In addition, a third core containing thick peat sequences was obtained outside this basin to ascertain the areal and temporal extent of the paleoenvironments. This core, designated SM08, was located in an interdistributary basin defined by Bayous Ferblanc and

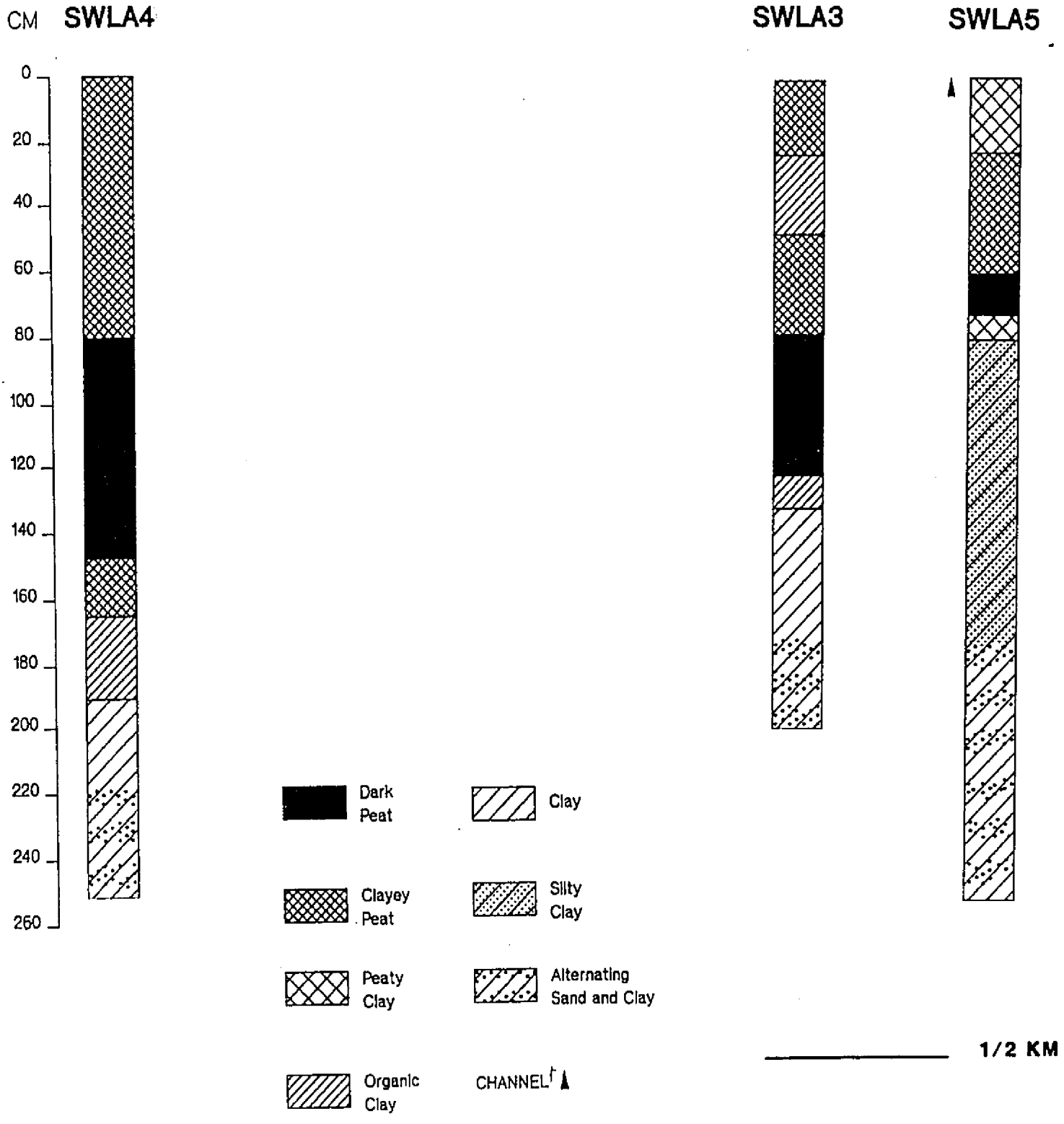
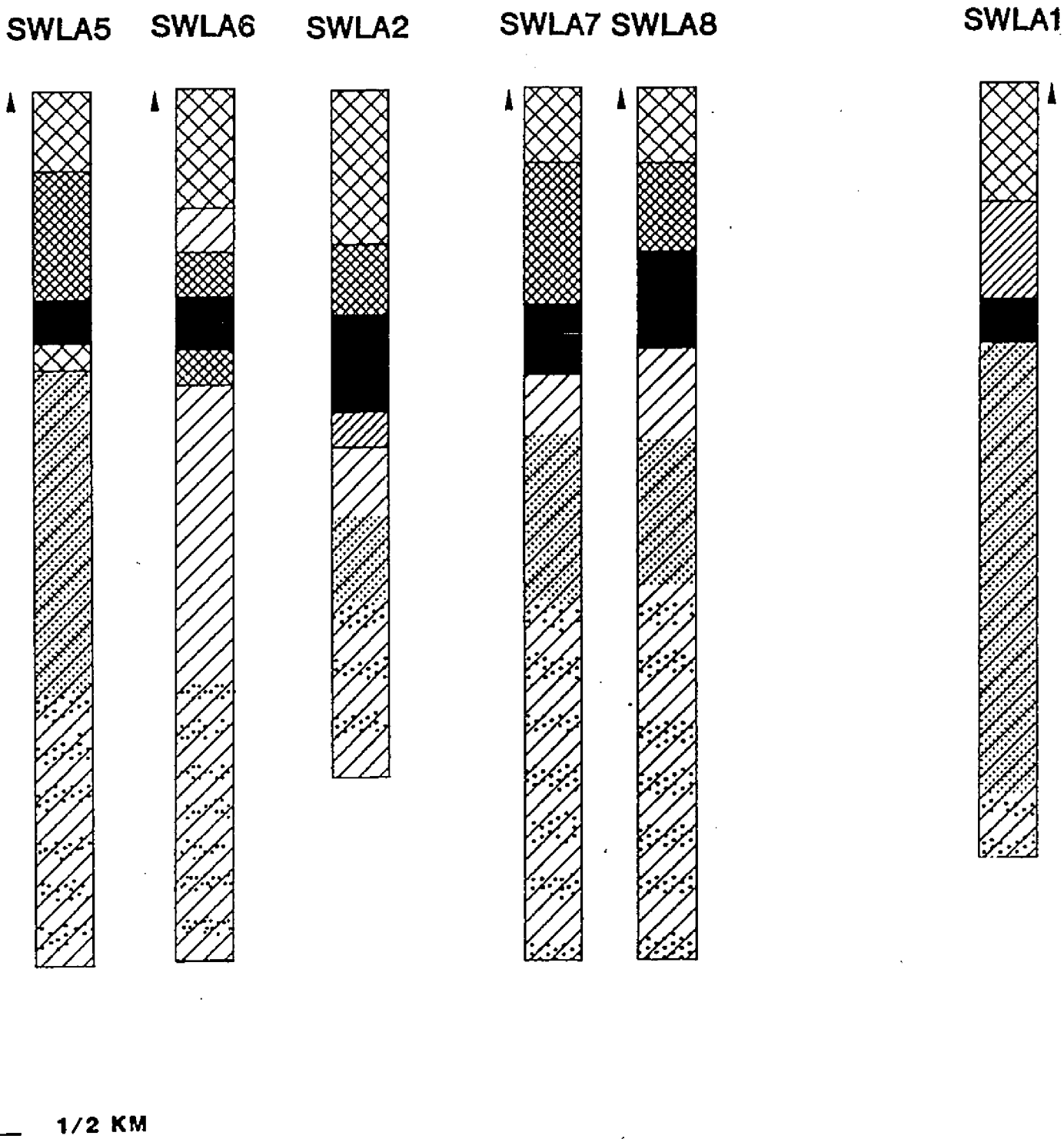


FIGURE 5. Lithology of Augers Along the S



Along the Southwest Louisiana Canal.

Jaque. The core was recovered approximately two miles north of the intersection between the Southwestern Louisiana Canal and Bayou Ferblanc (Figure 4).

Continuous three-inch-diameter cores were recovered utilizing a piston-coring device mounted on a portable tripod. The cores were stored frozen and subsequently split lengthwise in the laboratory. Qualitative descriptions of the sedimentary types were made during the laboratory sampling process. The qualitative descriptions of the sediments, in order of decreasing organic content, are dark peat, clayey peat, peaty clay, organic clay, gray clay, silt, and sand. The results of the visual descriptions are summarized below for each core. Figure 6 is a pictorial distillation of sedimentology.

Core SWLA4

Core SWLA4 was recovered from the central portion of the interdistributary basin located between the first and second channels due east of Bayou Lafourche. The 3 m core contained the thickest dark peat unit from the study area. The top 25 cm contained dark clayey peat with abundant root and rhizome organic matter. From 25 to 107 cm the peat became more clayey, containing decreasing amounts of macroscopically recognizable organic matter with depth. Dark fibrous peats were recovered between 107 to 188 cm. Within the interval from 188 to 266 cm, the organic content of the

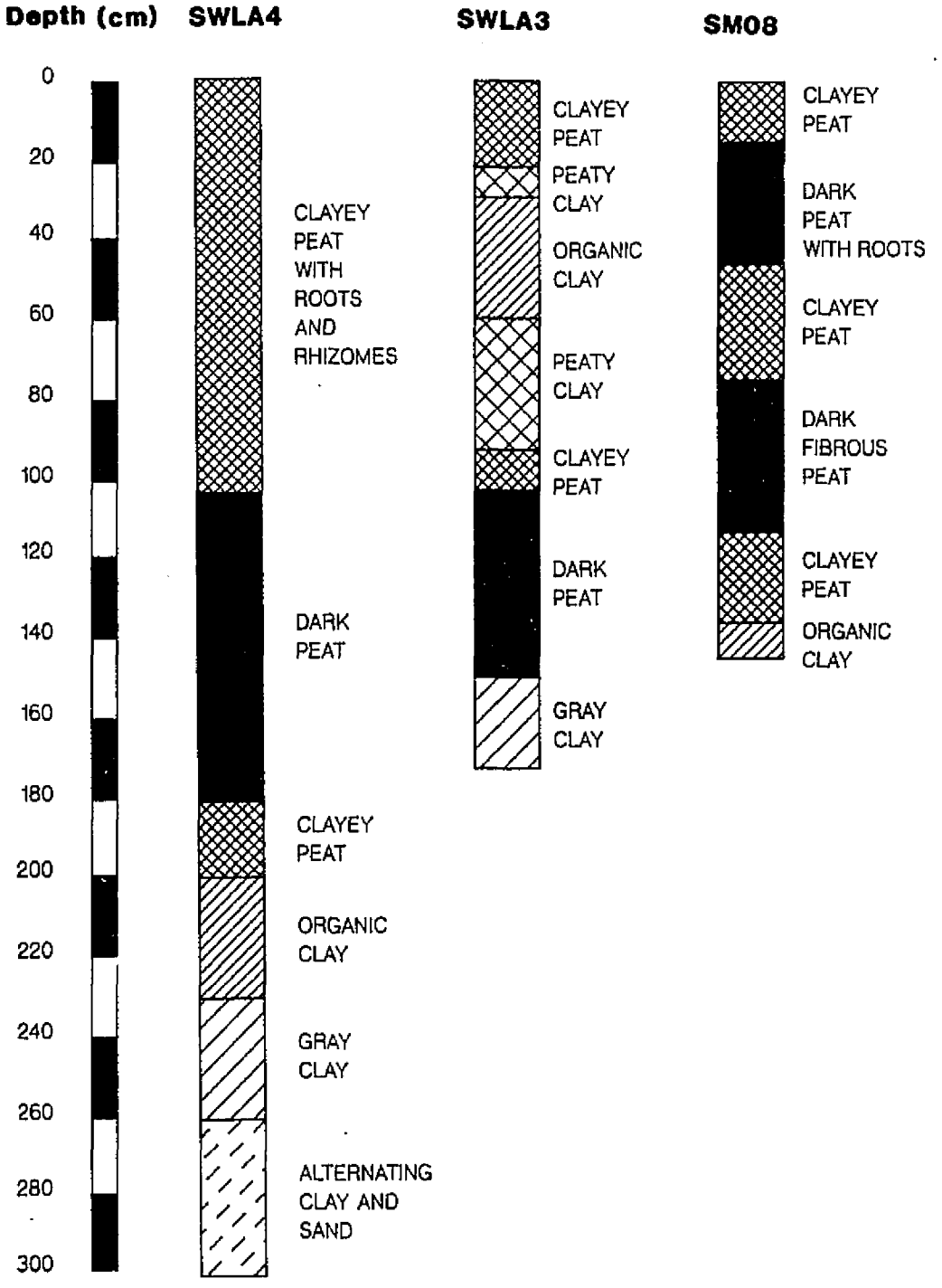


FIGURE 6. Lithology of Cores SWLA4, SWLA3, and SM08.

sediments gradually decreased from a clayey peat to an organic clay, and finally to a plastic gray clay. The basal portion of the core (266 to 302 cm) contained alternating layers of clay and sand.

Core SWLA3

Core SWLA3 was recovered in the same interdistributary basin as SWLA4, but more proximal to the eastern channel. The dark peat unit was substantially thinner in this core as compared to the unit in core SWLA4. Approximately two meters of core were recovered. The top 25 cm consisted of a clayey peat with root and rhizome organic matter. From 25 to 30.5 cm the organic content decreased to a peaty clay which graded into an organic clay between 30.5 to 61 cm. The organic content increased in the interval from 61 to 94 cm as peaty clays dominated. A clayey peat zone (94 to 102 cm) overlaid and sharply contacted a dark fibrous peat zone (102 to 155 cm). Below the dark peat, an organic clay zone extended from 155 cm to the bottom of the core at 175 cm.

Core SM08

Core SM08 was located in a different interdistributary basin from cores SWLA3 and SWLA4.

Overall, the sediments were more highly organic than those encountered in cores SWLA4 and SWLA3. The top 13 cm were clayey peats with root and rhizome organic matter,

which graded into dark peats between 13 to 46 cm. The dark peats graded into clayey peats in the interval between 46 to 76 cm. A dark fibrous peat was encountered between 76 and 114 cm. The basal section was characterized by a clayey peat (114 to 140 cm) which sharply contacted a basal organic clay layer from 140 cm to the bottom of the core at 147 cm.

IV. PALEOENVIRONMENTAL RECONSTRUCTIONS

The next three sections examine the methodologies and results that were utilized to reconstruct the environments of deposition for the three study cores.

The major emphasis of the reconstructions was to determine paleomarsh type through the analysis of fossil seed assemblages. Recognition of root and rhizomous material in buried peats was initially investigated as a method for determining paleomarsh type. A collection of root specimens from the major peat-forming plants of the Louisiana coastal marshes were collected and microscopically characterized. Oriented thin sections of buried peats from core SM08 were then prepared and analyzed. This technique was abandoned since relatively undecomposed root material from surface flora (*Spartina alterniflora*) was encountered at depths up to 1.5 meters. The presence of *Spartina alterniflora* roots at these depths indicated significant vertical migration of the root system. This vertical migration severely limits the usefulness of the root analysis approach. Seed analysis was therefore chosen as the method for reconstructing floral composition of the buried peats.

Salinity of the overlying marsh water is the most important factor regulating plant distribution in the Louisiana coastal wetlands. Paleosalinity analyses of the sediments from the three study cores provided an understanding of the relationships between salinity changes (in terms of magnitude and duration) and marsh type. Two fossil groups were utilized in the paleosalinity analyses. Marsh and estuarine foraminifera characterized the higher salinity regimes (>5 ppt), while sponge gemmules (reproductive bodies) were used to characterize the lower salinity ranges (<5 ppt). A combination of these two fossil groups adequately covered the spectrum of salinities encountered in coastal marsh and associated sediments.

V. FLORAL RECONSTRUCTIONS - SEEDS

Analysis of seeds (and other higher plant fruiting bodies) from buried peat deposits is a sensitive method for determining vegetation changes operative over short time periods and within a local geographical area.

Seed analyses have been successfully applied in paleobotanical studies. Baker (1965) used seeds and other plant microfossils to reconstruct the vegetational history of late-glacial sediments from Minnesota. Watts and Bight (1968) used seeds, in conjunction with pollen and molluscan fragments, to study a glacial lake deposit. Argus and Davis (1962) studied the macrofossils from a building excavation in Cambridge, Massachussets to reconstruct the vegetation during the Wisconsin late-glacial advance and retreat. Watts and Winter (1966) examined the seed assemblage from a Minnesota marsh core which was previously studied by pollen analysis. Watts and Winter concluded that the principles of pollen analysis as a reconstructive tool apply to seed analysis. Schofield and Robinson (1960) also correlated seed assemblages with the pollen record from a late post-glacial lake deposit and concluded that the macrofossil assemblage (seeds) better reflected the vegetation that fell immediately around the area of the

lake. However, the pollen assemblage was superior (as compared to the seeds) in detecting climatic changes. Coleman (1966) examined pollen and seed assemblages of Recent near-surface marsh sediments of the Louisiana coast. He found the seed assemblage to be most useful for characterizing the floral component of the peat. Pollen analysis recorded a more general marsh flora which consisted of the local environment in addition to adjacent communities.

It is therefore concluded that seed analysis is a viable paleobotanical tool that is sensitive to local vegetation changes in paleobotanical investigations.

Seed analysis was the technique used to reconstruct the vegetation history of peats and organic sediments in the three study cores. It is important to note that seed assemblages of the sediments did not reconstruct the exact marsh plant community in terms of species presence and abundance. The deposition and preservation of seeds are species dependent. The most important sources of variation affecting the seed assemblage are the number of seeds produced by a particular species, the preservability of the seed, and the reworkability of the seed. The paleoenvironmental determinations were accomplished by using key indicator species of marsh type in conjunction with the relative changes in the seed assemblages through time.

Methods

The split cores were sampled at 7.6 cm intervals, except where the interval contained visually different sedimentary types. In these cases, the sampling interval was either shortened or lengthened to accommodate the changing lithology.

Sample size was on a volumetric basis, the volume being proportional to the length of the sampling interval. Samples were derived in the following manner: Split core halves were surficially scraped to remove possible contamination. A semi-cylindrical sample was removed avoiding the 1.3 cm space that contacted the core barrel. From the semi-cylindrical volume, a 1.3 cm slab was cut away from the surface and retained for chemical analyses. Therefore, for the typical 7.6 cm sample interval, the calculated volume was approximately 90 cubic centimeters.

The sample was gently washed through a 200-mesh screen to remove clay-silt clasts and micro-organic particles. The residue was backflushed and retained in a beaker. Further separation into size classes was not undertaken to avoid loss of material, and to reduce preparational sources of error. Seeds (and other fossils) were isolated by meticulously wet picking successive sub-fractions of the residue. This task was accomplished using a

stereomicroscope (40x magnification) and a very fine brush (000 or 0000).

The taxonomic identification of the seeds utilized the following sources: (1) published descriptions, drawings, and photographs, (2) reference seeds from a Coastal Studies Institute collection, and (3) a collection of seeds from preserved specimens in the Louisiana State University Botany Department.

A morphotypic taxonomic system does not exist for seed identification as is commonly found in other paleontological fields. Identifications in the present study were made by matching the fossil seeds with photographs, drawings, and collected specimens. However, several excellent seed atlases exist and were extensively used in this study (Martin and Barkley, 1961; Beijerinck, 1947; Berggren, 1969). In addition, several plant manuals provided descriptions and drawings of seeds (Hitchcock, 1950; Mason, 1957; Radford et al., 1968; Fassett, 1969; Hotchkiss, 1970; and Pohl, 1975).

The abundance of seeds for each taxon is reported on an ordinal (categorical) scale of measurement. Duplicate analyses of several samples revealed poor reproducibility when using a continuous numerical measuring procedure. Excellent reproducibility was achieved when an ordinal scheme was employed. Therefore, the abundance of seeds for

each taxon is reported based on the following ordinal system:

rare	< 3 seeds	per 90 cc
rare to common	3-5 seeds	per 90 cc
common	6-10 seeds	per 90 cc
common to abundant	11-15 seeds	per 90 cc
abundant	16-20 seeds	per 90 cc
very abundant	> 20 seeds	per 90 cc

Results

Thirty eight seed taxa were identified from the three study cores. Plant fragments of *Spartina alterniflora* and fish scales were also reported with the seed analysis. Photographs of each seed type, morphologic descriptions, and identification clues are presented in Appendix I.

The occurrence and abundance of the seeds, plotted against depth, are graphically tabulated for each core in Figures 7-9. Plant taxa are arranged in order of decreasing salinity tolerance, as best determined from published data (Penfound and Hathaway, 1938; Penfound, 1952; Chabreck, 1972).

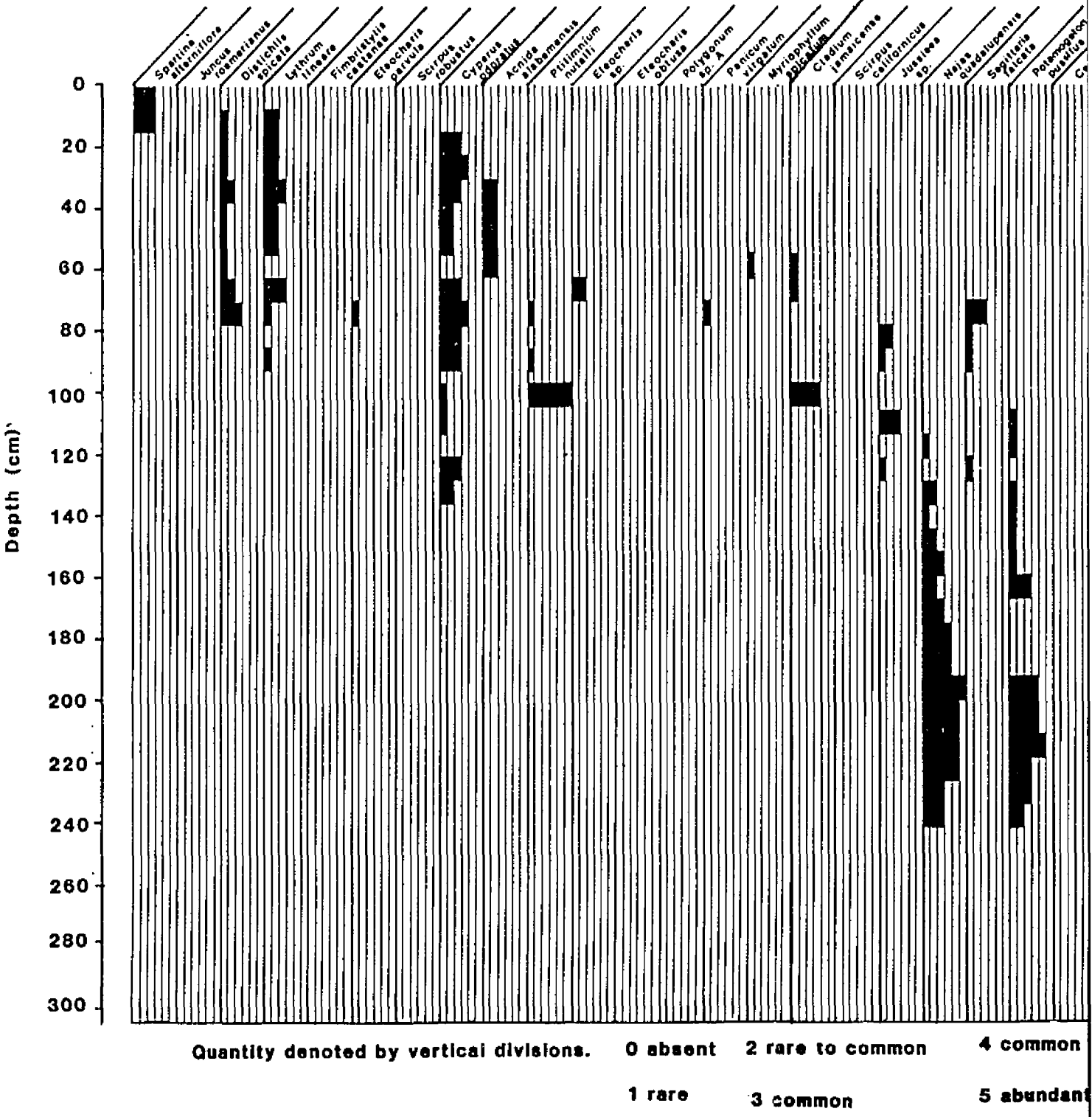
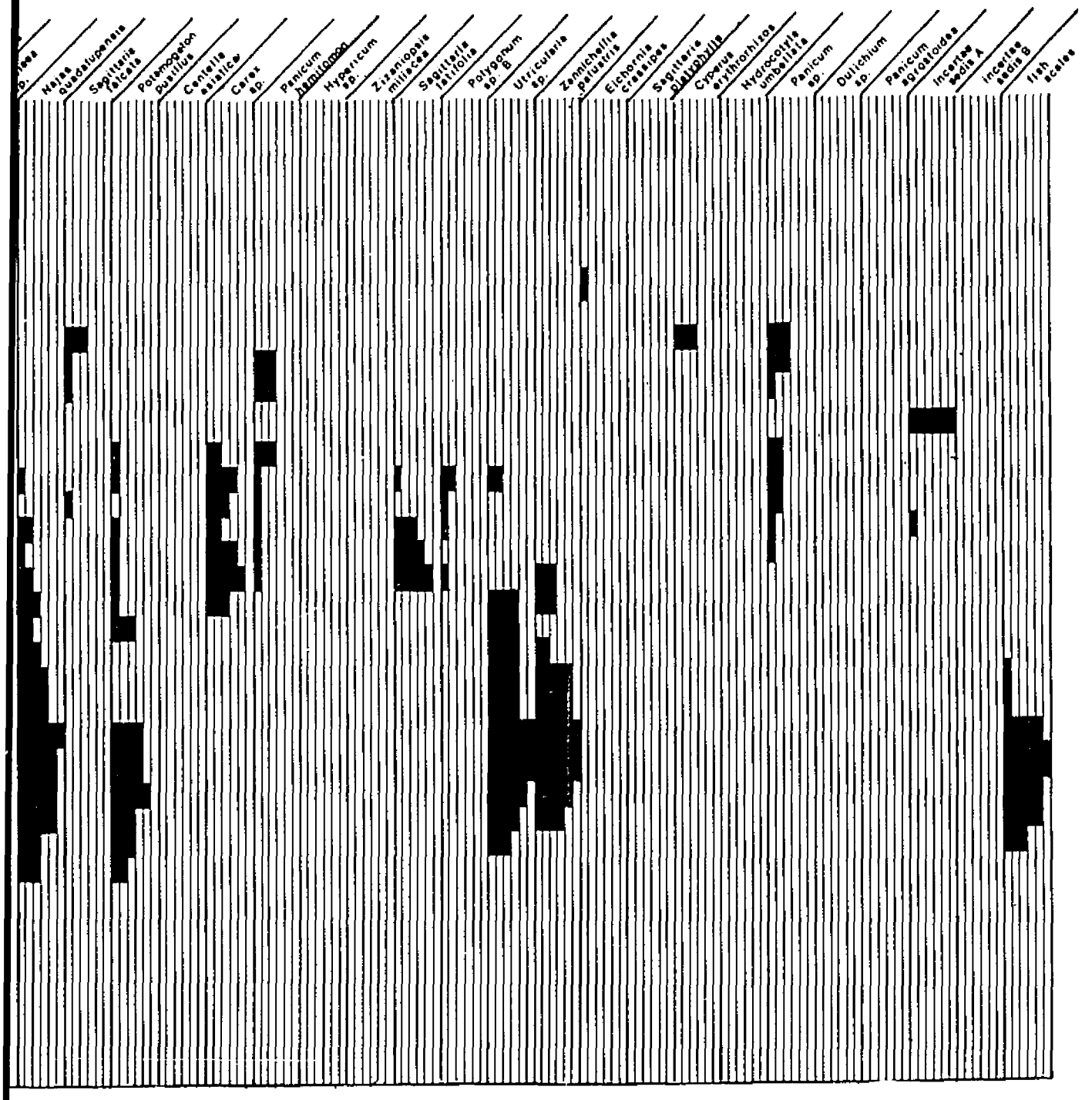


FIGURE 7. Depth Distribution of Seeds in C



n 4 common to abundant 6 very abundant

5 abundant

of Seeds in Core SWLA4.

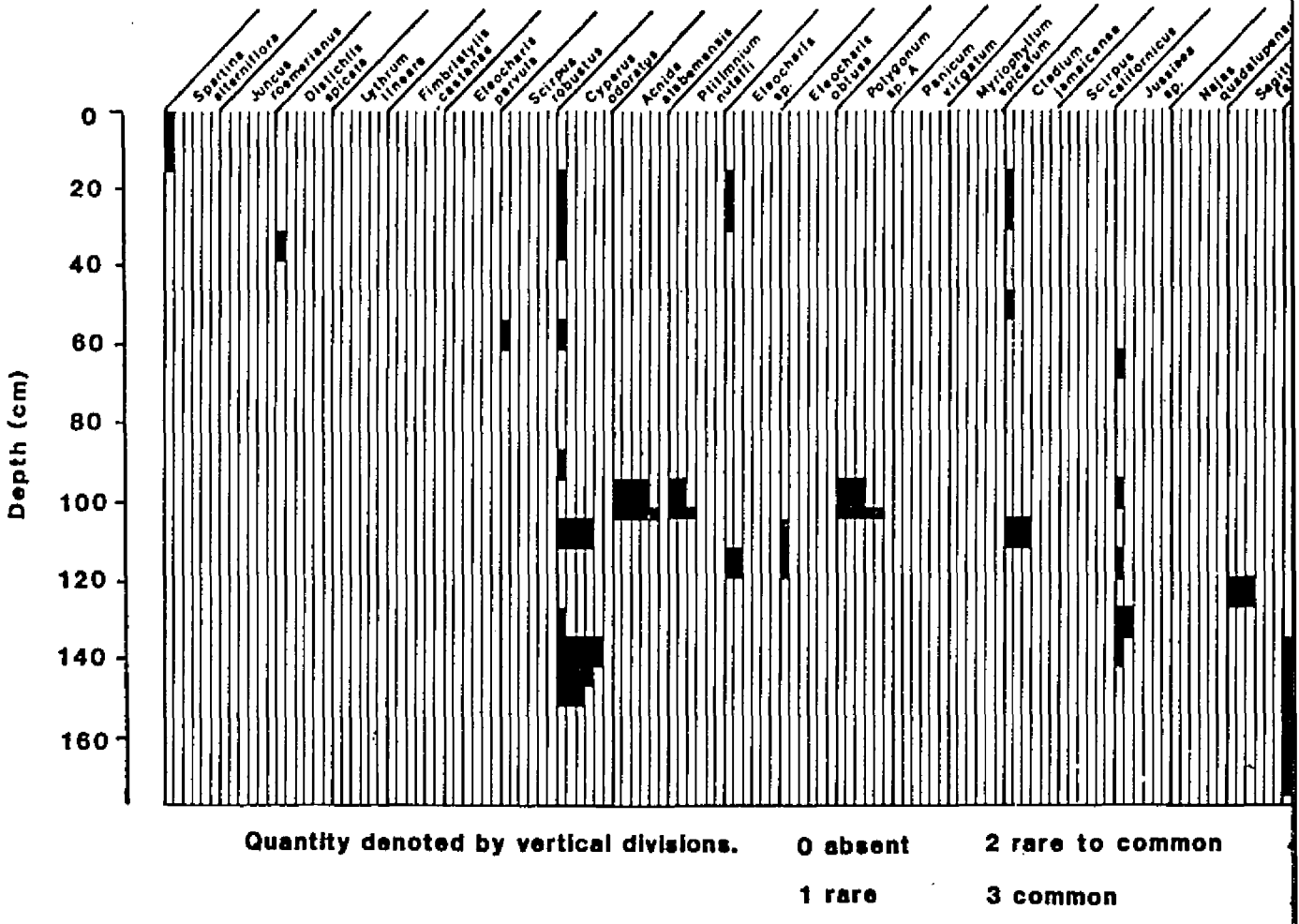
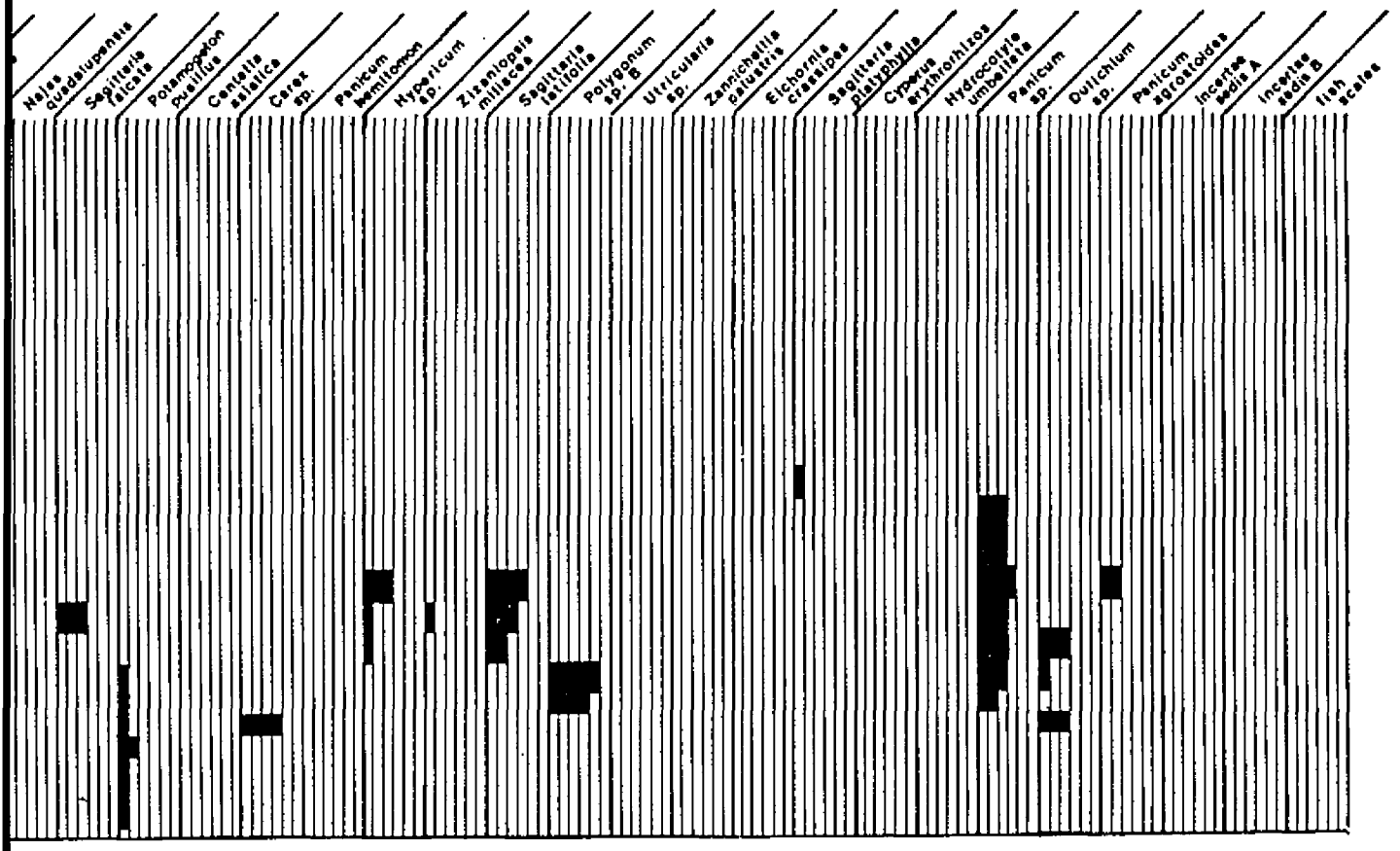


FIGURE 8. Depth Distribution of Se



non 4 common to abundant 6 very abundant

5 abundant

of Seeds In Core SWLA3.

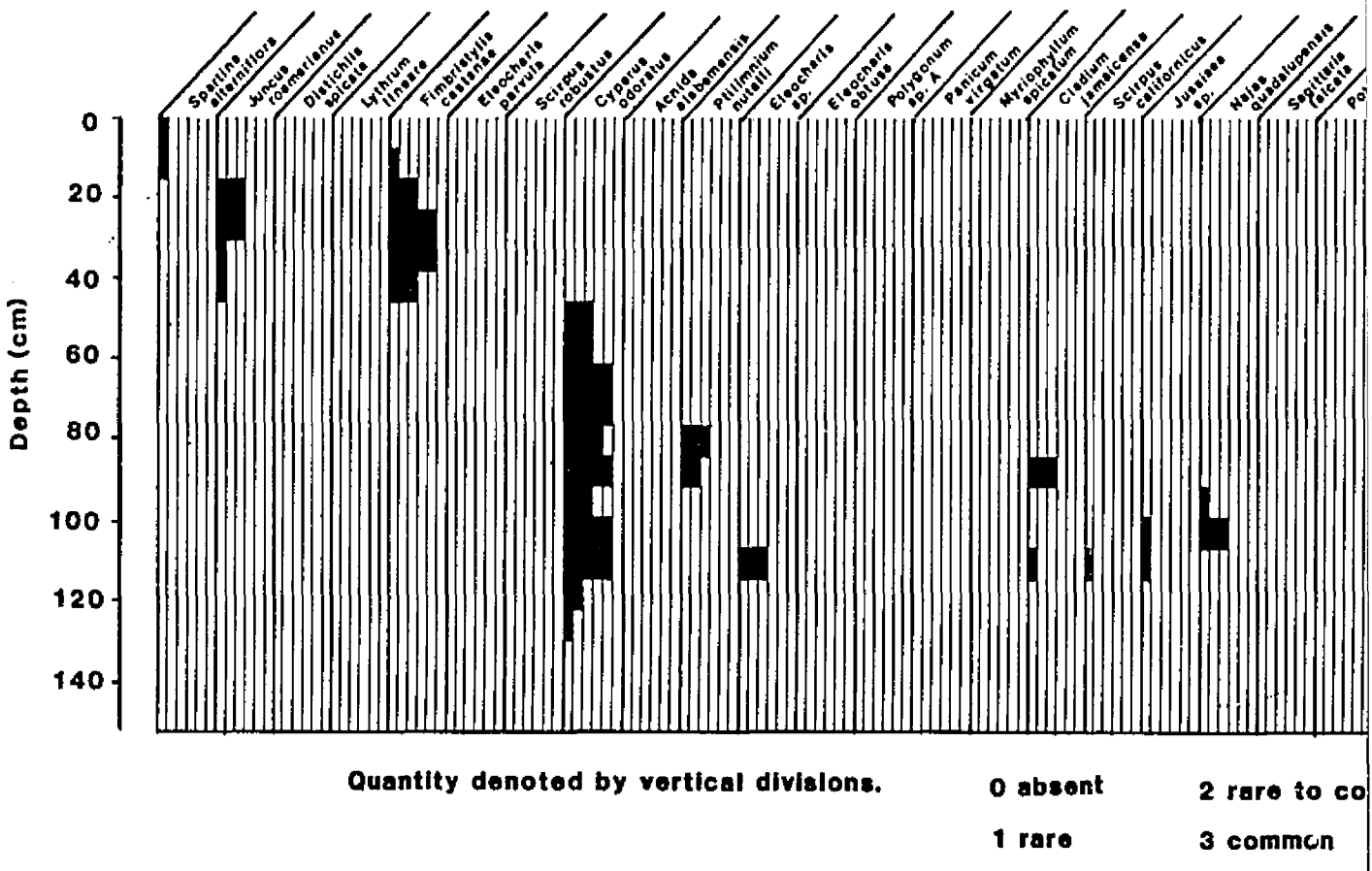
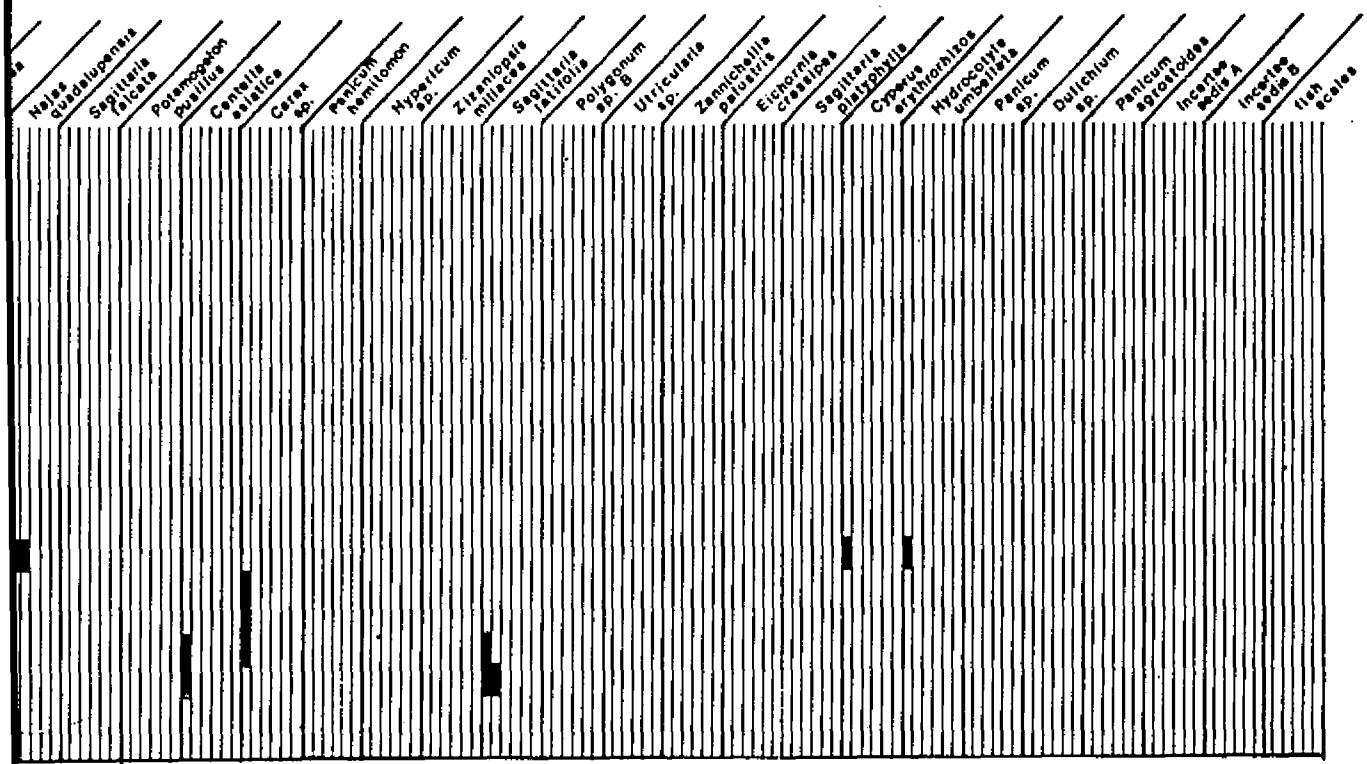


FIGURE 9. Depth Distribution of Seeds In



rare to common

common

4 common to abundant

5 abundant

6 very abundant

Seeds in Core SM08.

Reconstructing the floral history of a cored sequence was approached by describing the seed assemblages from the bottom of the core to the top. This procedure aided the interpretation of paleoenvironments by recreating the historical development of the deposits.

Determination of paleomarsh type was accomplished by comparing the fossil seed assemblages with the present-day plant distributions. Reconstructed marsh types were divided into depth intervals. The use of zonations is not meant to imply discrete events, but rather to simplify the reconstruction of the sedimentary sequence.

Core SWLA4

The greatest species richness and abundance of seeds were recovered from core SWLA4. Twenty-six of the 40 seed types were encountered from this core. A graphical representation of the data is presented in Figure 7.

The bottom section of the core (302 to 241 cm) was totally devoid of seeds. These sediments consisted of organic lean, alternating clay and sand layers. The absence of seeds suggests that no vegetation was locally present in the area.

The first record of a plant community was encountered at 241 cm. Common occurrences of *Najas quadalupensis* and

Potamogeton pusillus seeds in this interval indicated the presence of a freshwater community in a pond or lake between one and ten acres in area.

Maximum development of the submerged community occurred in the interval from 199 to 226 cm. The seed assemblage consisted of abundant to very abundant quantities of seeds from the submerged angiosperms *Utricularia sp.* and *Zannichellia palustris*. Fish scales, also indicative of a pond or lake environment, occurred in abundant to very abundant quantities. The presence of *Utricularia sp.* and *Zannichellia palustris* indicated a small pond size, on the order of .1 to 1 acres. The reduction in pond size was a result of infilling processes.

The interval from 174 to 199 cm marked an overall reduction in the quantity of seeds supplied to the sediments from the submerged community. Within this interval, *Zannichellia palustris* seeds decreased to common quantities, *Utricularia sp.* seeds decreased from very abundant to abundant, *Najas quadalupensis* seeds decreased from very abundant to rare-common, *Potamogeton pusillus* disappeared, and fish scales were almost totally absent. The reduced overall abundance of the submerged community points to a further lowering of water levels in response to continued infilling of the pond.

Formation of the first marsh vegetation occurred at 174 cm as indicated by the appearance of common quantities of *Carex sp.* seeds.

Abundant numbers of *Carex sp.* seeds, along with common to abundant numbers of *Sagittaria latifolia* seeds, and rare to common numbers of *Polygonum sp. B* seeds, dominated the interval from 116 to 166 cm. These species occupied slightly elevated fresh marsh sites. Also within this interval, the submerged community continued to decrease, while seeds of *Panicum hemitomon*, *Panicum sp.*, and *Cyperus odoratus* were found in very low abundances. The total seed assemblage for this interval revealed that these peats were deposited in a slightly elevated fresh marsh situated between a pond and a *Panicum* marsh. Low numbers of seeds from these adjacent environments were deposited into the slightly elevated fresh marsh.

The interval from 77 to 116 cm represents peats that were deposited in a *Panicum* marsh, as determined by the presence of seeds from *Panicum hemitomon*, *Panicum sp.*, *Cyperus odoratus*, and *Jussiaea sp.* Within this section is an interval (97 to 104 cm) containing abundant seeds of *Ptilimnium nutalli*, *Cladium jamaicense*, and an unidentifiable pod-like fossil designated *Incertae sedis A*. The nature of the brief appearance of this assemblage is

unexplainable, however, similar assemblages occurred at comparable depths in cores SWLA3 and SM08.

The seed assemblage abruptly changed at 77 cm due to the sudden disappearance of the *Panicum* community. The zone from 15 to 77 cm contained seeds of euryhaline marsh plants. This interval is characterized by the seeds of *Cyperus odoratus*, *Lythrum lineare*, *Panicum virgatum*, *Distichlis spicata*, *Acnida alabemensis*, *Eleocharis sp.*, *Eleocharis parvula*, *Sagittaria falcata*, *Myriophyllum spicatum*, and *Cladium jamaicense*. All of these species (except for *Cladium jamaicense*) can exist in the fresh, intermediate, or brackish marshes. However, the majority of these species achieve their maximum abundance in the intermediate marsh type. Therefore, by definition, the environment of deposition during this interval was an intermediate marsh.

The top of the core to 15 cm was markedly impoverished in seed abundance and species richness. This interval contained lemma fragments of *Spartina alterniflora*, and rare-common abundances of *Distichlis spicata* and *Lythrum lineare*. This 15 cm interval represented the recent development of blanket saline marshes.

A review of the marsh environments for the peat sequence at SWLA4 is depicted in Figure 10.

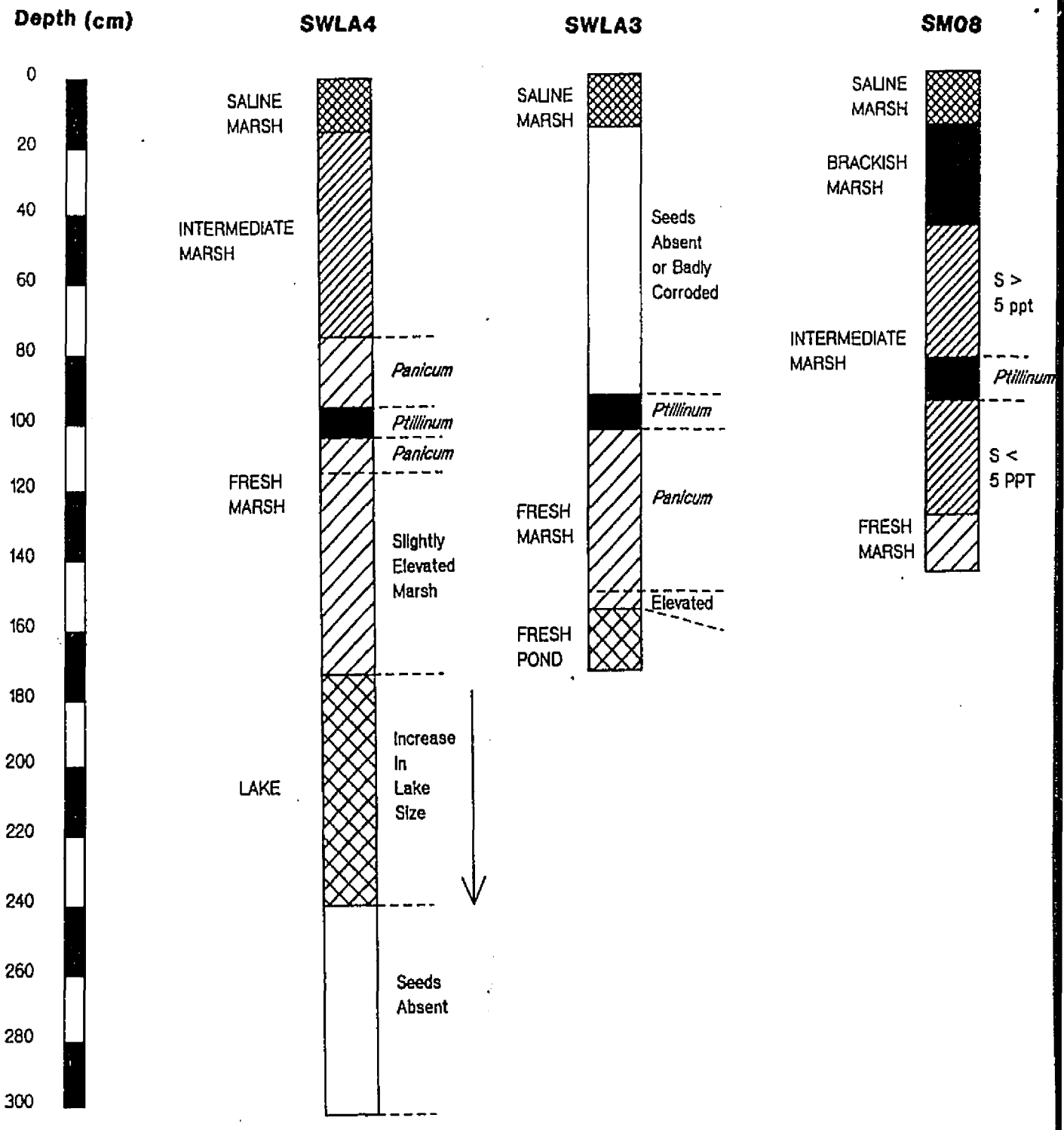
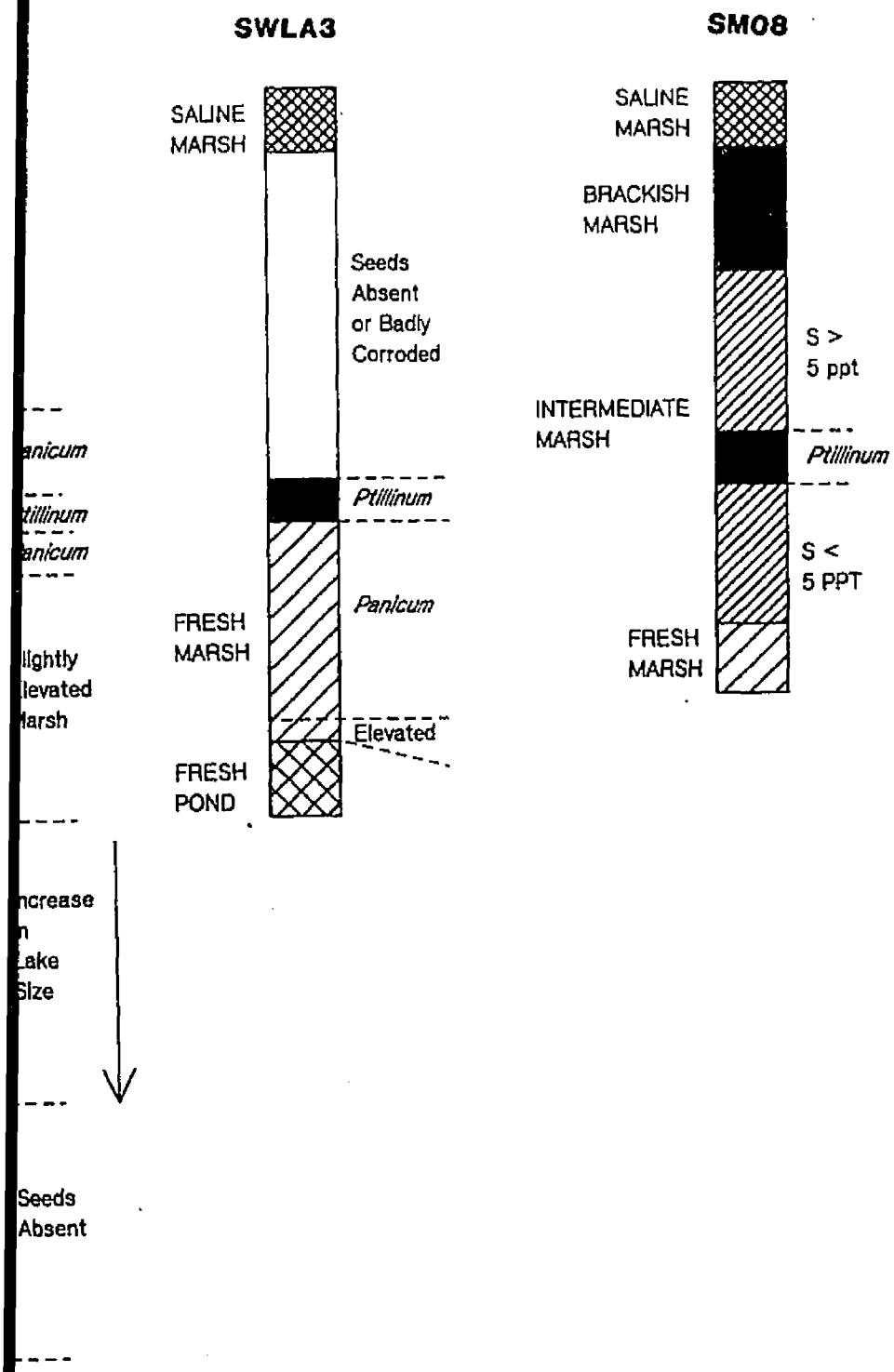


FIGURE 10. Review of Paleovegetation Analysis for Cores SWLA4, SWLA3, ar



ovegetation Analysis for Cores SWLA4, SWLA3, and SM08.

Core SWLA3

Twenty seed types were encountered during the analysis of core SWLA3. The seed assemblage depth distributions are illustrated in Figure 8.

The first record of vegetation occurred at 175 cm, characterized by rare numbers of *Potamogeton pusillus* seeds. This monospecific zone continued to 157 cm and is interpreted as representing a submerged pond community.

High abundances of *Carex sp.*, *Dulichium sp.*, and *Cyperus odoratus* seeds defined a narrow 5 cm zone from 152 to 157 cm. This assemblage is characteristic of a slightly elevated fresh marsh.

The interval from 104 to 157 cm was dominated by the seeds of *Panicum sp.*, *Sagittaria latifolia*, and *Polygonum sp. B*. The top 8 cm of this section also contained the seeds of *Cladium jamaicense* and *Hypericum sp.* The entire interval represents a fresh *Panicum* marsh, consisting of salinity-intolerant fresh marsh species.

The seed assemblage from 94 to 104 cm consisted of abundant seeds of *Ptilimnium nutalli*, *Acnida alabemensis*, and *Polygonum sp. B*. This 10 cm interval may be ecologically similar to the *Ptillinum nutalli* zones in cores SWLA4 and SM08.

At 94 cm the sediments sharply changed from fairly organic clayey peats to organic lean peaty clays. The relatively low organic sediments continued to a depth of 23 cm. Coincident with the low organic sediments, seeds were rarely encountered and poorly preserved. The seed species recovered were *Jussiaea sp.*, *Cladium jamaicense*, *Eleocharis sp.*, *Cyperus odoratus*, *Scirpus odoratus*, and *Distichlis spicata*. These sediments were deposited in a brackish lake environment (as will be demonstrated in the next section on foraminifera). The seeds supplied to the lake sediments were derived from surrounding intermediate and brackish marshes. The poorly preserved condition of the seeds indicate significant areal transportation.

The top 15 cm of the core contained rare numbers of lemma fragments from *Spartina alterniflora*. This 15 cm interval represented the recent deposition of saline marsh peats.

A review of the depositional environments encountered in core SWLA3 is depicted in Figure 10.

Core SM08

Core SM08 contained the lowest species richness of seed types, with only 15 taxa encountered. The seed assemblage distribution chart is presented in Figure 9.

The basal portion of the core was noticeably devoid of seeds from a submerged community. The first appearance of vegetation occurred at 145 cm containing rare to rare-common seeds of *Sagittaria latifolia*, *Centella asiatica*, and *Carex sp.* A fresh marsh habitat of low species richness occurred during this time. This basal zone continued to a depth of 130 cm.

From 130 to 99 cm the seed assemblage became more diverse with the introduction of abundant numbers of *Cyperus odoratus* seeds and intermittent and low numbers of seeds from *Carex sp.*, *Hydrocotyle umbellata*, *Cyperus erythrorhizos*, *Najas quadalupensis*, *Scirpus californicus*, *Jussiaea sp.*, *Cladium jamaicense*, and *Eleocharis sp.* The absence of *Panicum* and *Polygonum* seeds in this interval, in conjunction with the presence of salinity-tolerant species, indicates a slightly saline depositional environment. The paleoenvironment was therefore an intermediate marsh; however, the salinity never exceeded 5 ppt due to the presence of some fresh marsh species.

Ptilimnium nutalli briefly appeared in the interval from 99 to 84 cm (along with *Cladium jamaicense* and *Cyperus odoratus*). This zone may be florally analogous to the intervals encountered in SWLA4 (96 to 104 cm) and SWLA3 (94 to 104 cm).

High abundances of *Cyperus odoratus* seeds dominated the florally monospecific peats from 84 to 46 cm. This interval represented an intermediate marsh influenced by salinities over 5 ppt. Interpretation of marsh type is based on the disappearance of the salinity-intolerant species, and the continuation of salinity-tolerant *Cyperus odoratus*.

Within the interval between 46 to 15 cm, seeds of *Juncus roemerianus* and *Fimbristylis castanae* dominate the assemblage. The depositional environment occurring during this time is therefore interpreted as a brackish marsh.

The top 15 cm of the core contained lemma fragments of *Spartina alterniflora*. This section represented the recent development of the saline marsh.

A review of the depositional environments for core SM08 is depicted in Figure 10.

VI. PALEOSALINITY ANALYSIS - FORAMINIFERA

Foraminifera are capable of adapting to a wide range of environmental conditions. These predominantly marine organisms have been recovered from such extreme environments as hypersaline non-marine lakes (Cann and DeDeckker, 1981), and an oligohaline estuarine zone (McCrone and Schafer, 1966). Marsh foraminifera are represented by a cosmopolitan assemblage, capable of tolerating wide ranges in environmental conditions. There is strong evidence that the distribution of some marsh foraminiferids are controlled by salinity (Parker and Athearn, 1959). Therefore, the foraminifera assemblages in this study were used to determine paleosalinity.

Marsh foraminifera predominantly construct arenaceous tests in response to low pH (Phleger, 1970) or low dissolved carbonates (McCrone and Schafer, 1966). Hyaline foraminifera have been found to occur in marsh-estuary environments when average salinities exceeded 15 ppt (Ellison, 1972).

Marsh assemblages have characteristically low diversities, patchy spatial distributions, and extremely variable population densities (Murray, 1971). Studies of living foraminifera have suggested several ecological hypotheses

for their temporal and spatial distributions. Lee (1974), and Matera and Lee (1972) suggested that since foraminifera are selective and opportunistic feeders, they tended to cluster around heterogeneous, localized food sources. Phleger and Walton (1950) encountered large foraminiferal populations in the high marsh where organic productivity was greatest. Price (1980) hypothesized that the distribution of salt marsh foraminifera may be controlled by competition for resources rather than by tolerance of physical conditions. Steineck and Bergstein (1979) suggested that certain foraminifera species may respond to redox conditions and sulfide concentrations. In their study of a New York salt marsh they encountered only two species (*Amobaculites exigus* and *Ammonia becarrii*) in stringent anaerobic sediments.

Parker and Athearn (1959) studied the distribution of marsh foraminifera in a Massachusetts marsh. The salinity of the marsh waters varied from almost non-marine (with some tidal influence) to near marine. They observed *Trochammina inflata* and *Jadammina polystoma* to increase in abundance with increasingly marine conditions. Conversely, *Arenoperella mexicana*, *Haplophragmoides hancocki*, *Tiphotrocha comprimata*, and *Trochammina marcescens* decreased in abundance with increasingly marine conditions. The remaining species encountered in the study fluctuated independent of salinity.

Foraminifera from a south California marsh consisted of typical marsh assemblage in terms of species presence and abundance (Scott, 1976). In addition, a new species, *Polysaccamina ipohalina*, was found to be restricted to the brackish marsh, and suggested as a paleo-marker for this environment.

The lower salinity limit of foraminiferid occurrence is approximately 5 ppt. This lower limit was determined from a study of Hudson River estuarine foraminifera (McCrone and Schafer, 1966). Furthermore, as the salinity approached 5 ppt, two species (*Trochammina marcescens* and *Ammonia spp.*) were observed to have pseudo-chitonous tests (as opposed to agglutinated tests under normal saline marsh salinity).

In estuarine and intertidal zones, with average salinities above 15 ppt, calcareous hyaline foraminifera can exist (Ellison, 1972). The predominant hyaline foraminifera belong to the genera *Elphidium* and *Ammonia*. These hyaline forms occur in bays and restricted saline lakes and may be transported to adjacent marshes by tides.

Three studies of the foraminifera distribution within environments of the Mississippi deltaic plain are of particular importance to this study.

Waldron (1963) studied the foraminifera of Timbalier Bay, Louisiana. Species encountered throughout the bay were *Ammotium dilatatum*, *Elphidium gunteri*, *Elphidium matagoratum*, *Ammonia parkinsonia*, and *Ammonia tepida*.

Byrne et al. (1959) recognized four faunal zones from core material underlying the Chenier Plain, Louisiana. The *Strebulus (Ammonia)* zone contained predominantly *Strebulus parkinsonia*. High abundances of *Strebulus* were reported from sedimentary environments experiencing large fluctuations in salinity (Kruit, 1955). The environment of deposition assigned to the *Strebulus* zone in the Chenier Plain was a restricted pond, lake, or embayment encountering extreme salinity variations brought on by periodic flooding and evaporation. A *Strebulus-Elphidium* zone represented normal marine shallow-water environments with minor salinity variations. A *Quinqueloculinid* zone was indicative of a deep-water environment. The fourth zone described encompassed mudflats and marshes, and was designated the *Trochammina* zone. The species recovered from this environment were *Trochammina comprimata*, *Milliamina fusca*, *Ammobaculites sp.*, *Recurvoides sp.*, and *Ammostuata inepta*.

Phleger (1955) studied the distribution and ecology of foraminifera from the active Mississippi delta. This study recognized a marsh assemblage, consisting of the species *Ammostuata inepta*, *Arnoperella mexicana*, *Leptodermella*

variabilis, *Miliamina fusca*, and *Trochammina marcescens*. No indication of the marsh type or salinity regime was reported.

A review of the salinity relationships of marsh and estuarine foraminifera is presented in Table I. These relationships were used in this study to reconstruct the salinity histories from the three study cores.

Methods

Foraminifera were isolated during the process of seed picking. Sample preparation was described in the methodology section of the seed analysis. It should be noted that a wet picking method (used in this study) is more time consuming than a routine dry picking technique. However, wet picking insured excellent morphological integrity of the delicate agglutinated structures. These delicate structures would be severely altered or destroyed during dry picking, greatly altering the usefulness of the technique.

Results

Twelve foraminifera taxa were recovered from the three study cores. Agglutinated forms were most commonly encountered and consisted of the following taxa: *Trochammina inflata*, *Jadammina polystoma*, *Haplophragmoids sp.*,

TABLE I. FORAMINIFERA SALINITY INDICATORS

ASSEMBLAGE	SALINITY INTERPRETATION	REFERENCE
Trochammina inflata *Jadammina polystoma*	High relative abundances indicate more marine conditions	Parker and Athearn, 1959
Trochammina marcescens *Tiphotrocha comprimata* *Arenoperella mexicana* *Haplophragmoides*	High relative abundances indicate less marine conditions	Parker and Athearn, 1959
Pseudo-chitonous forms of *Trochammina marcescens* and *Ammonia spp.*	Salinity approximately 5 ppt	McCrone and Schafer, 1966
Ammonia spp. predominates	Fluctuating salinity with hypersaline events	Krult, 1955 Byrne et al., 1959
Ammonia spp. *Elphidium spp.*	Stable salinity greater than 15 ppt	Ellison, 1972 Byrne et al., 1959

Arenoparrella mexicana, *Trochammina marcescens*, *Tiphotrocha comprimata*, *Recurvoides sp.*, *Miliammina fusca*, *Ammoastuata inepta*, and *Ammotium salsum*. Two taxa, *Ammonia spp.*, and *Elphidium spp.*, comprised the hyaline forms. The agglutinated and hyaline forms were typical of the cosmopolitan assemblages encountered in other marsh and restricted embayment environments. Microphotographs and descriptions of each taxon are presented in Appendix II.

Figures 11-13 depict the relative abundance of each taxon plotted against depth for cores SWLA3, SWLA4, and SM08. The depths used in the plots are the mean for the sampling interval. The total number of foraminifera encountered at each sample depth is also presented in the figures.

The first appearance of foraminifera occurred at approximately the same depth in each core (76 cm in SM08, 85 cm in SWLA4, and 94 cm in SWLA3). Furthermore, the foraminifera were continuously present from these depths to the surface of the cores. The first appearance of foraminifera at comparable depths in all three cores suggests a contemporaneous basinwide salinity event. The paleosalinity at the time of the first foraminifera appearances was approximately 5 ppt (the lower salinity tolerance of the foraminifera).

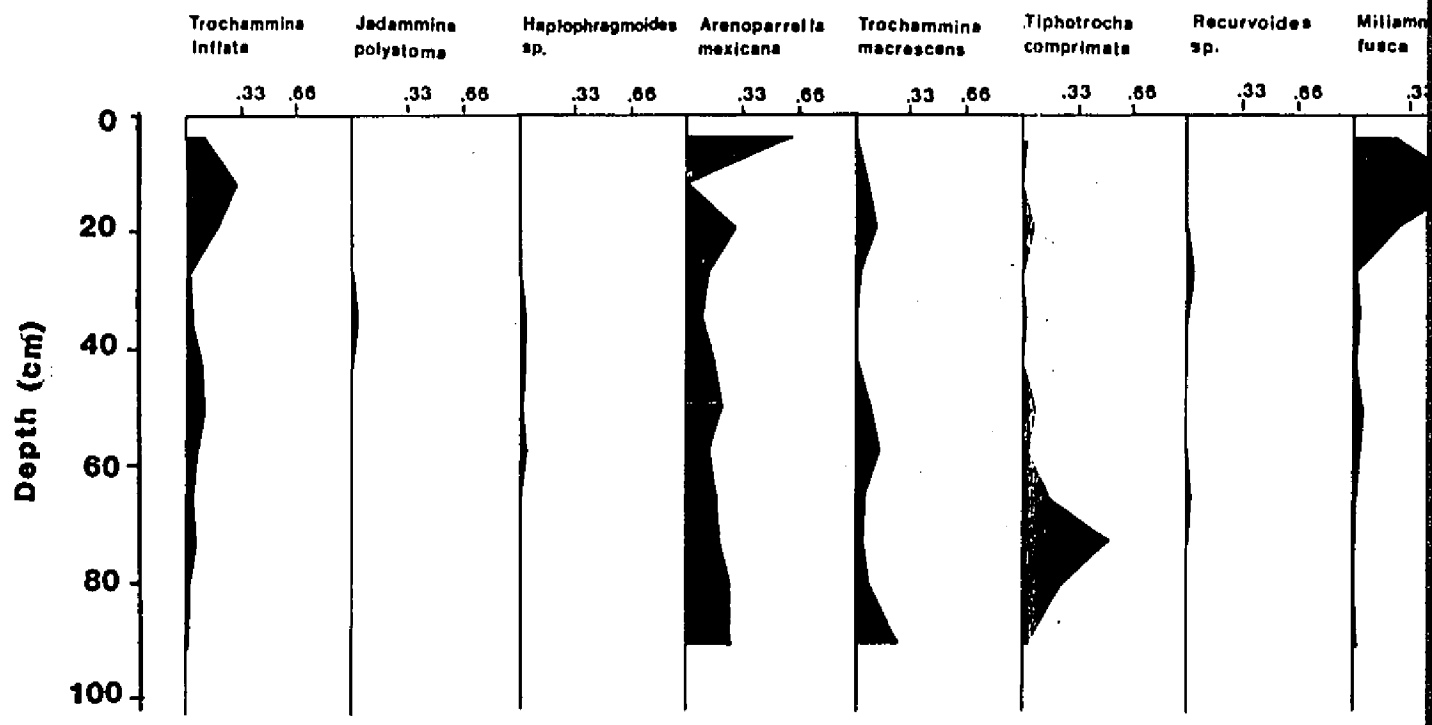
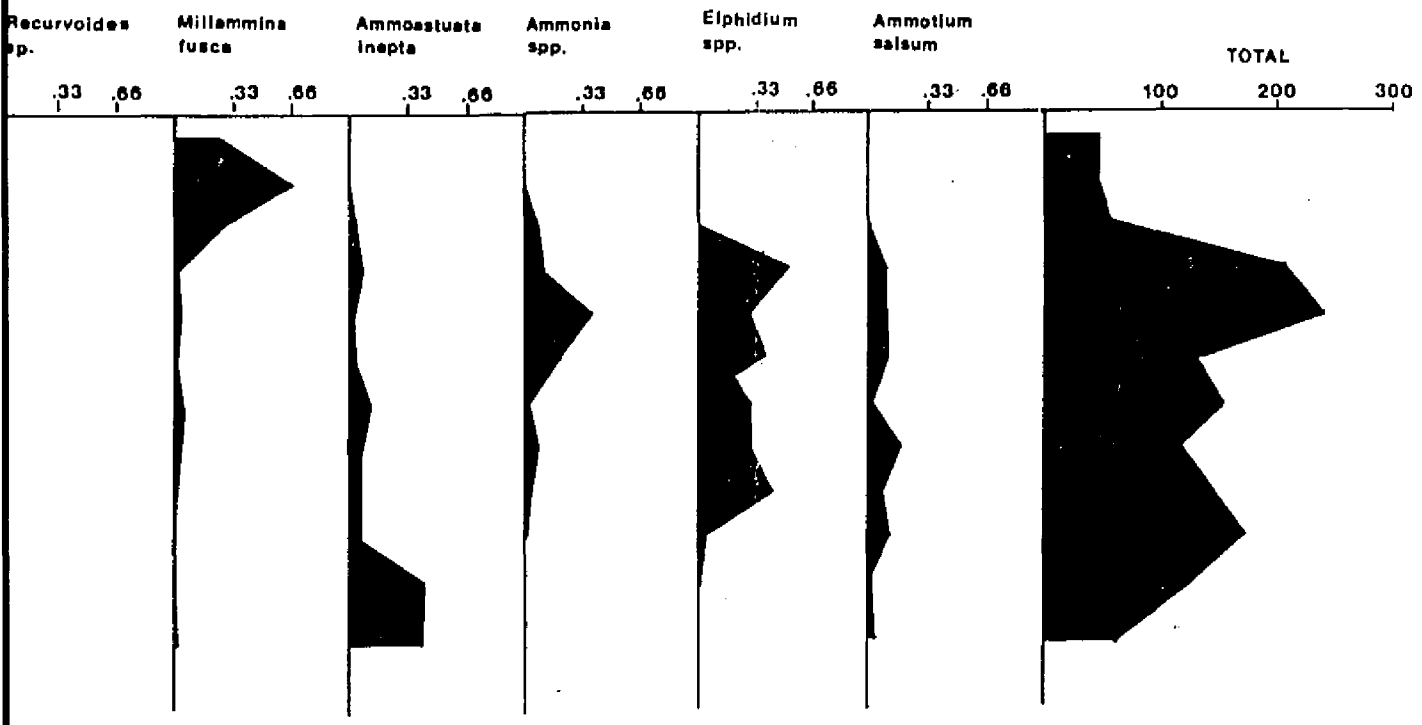


FIGURE 11. Foraminifera Depth Distribution



n Distribution in Core SWLA3.

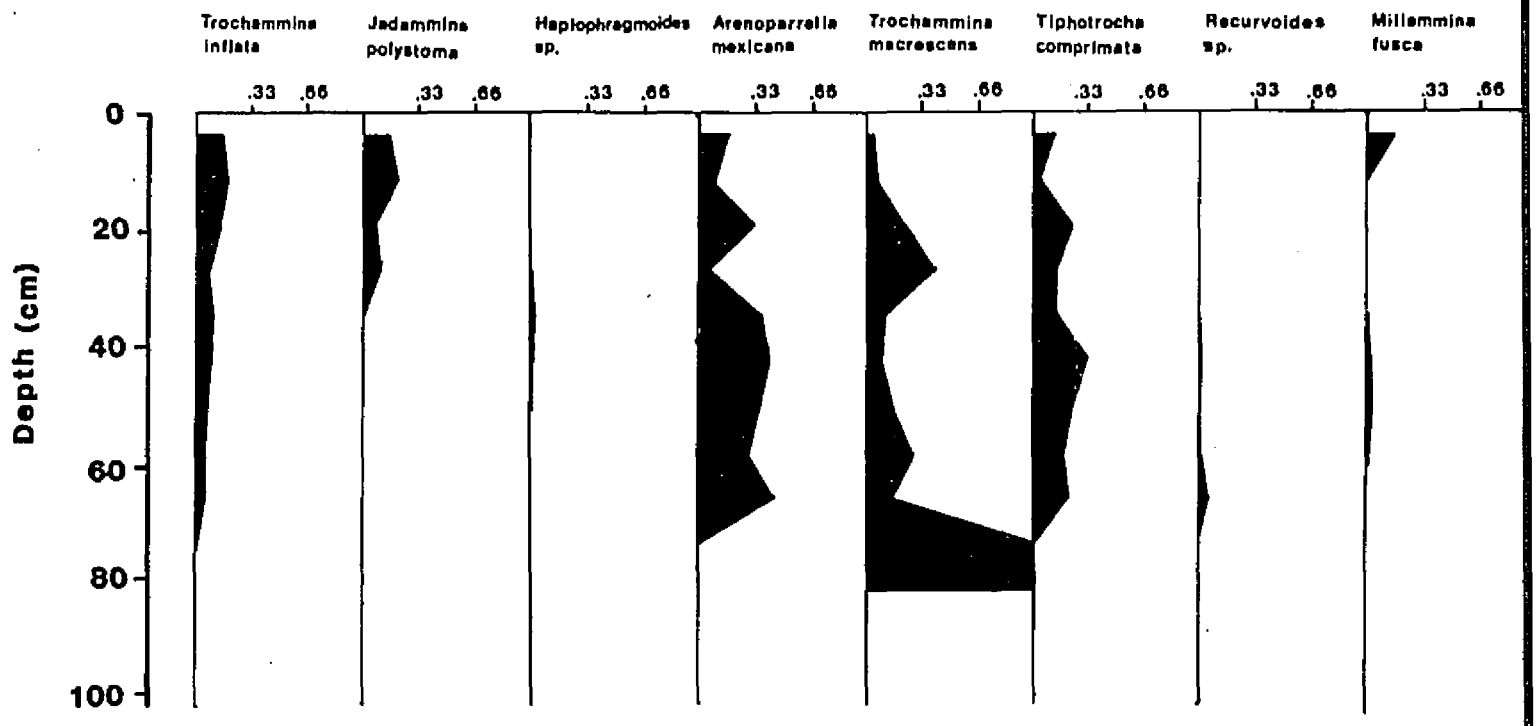
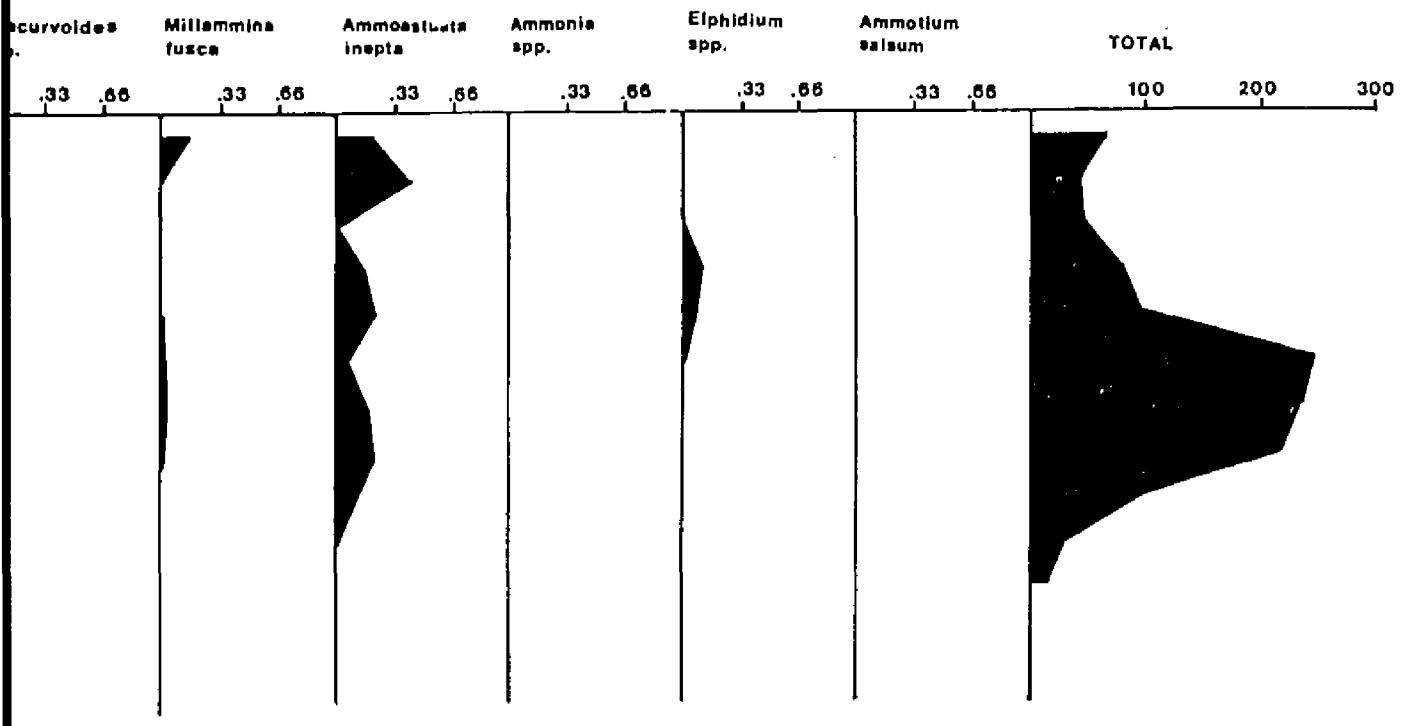


FIGURE 12. Foraminifera Depth Distribution in Co



Distribution in Core SWLA4.

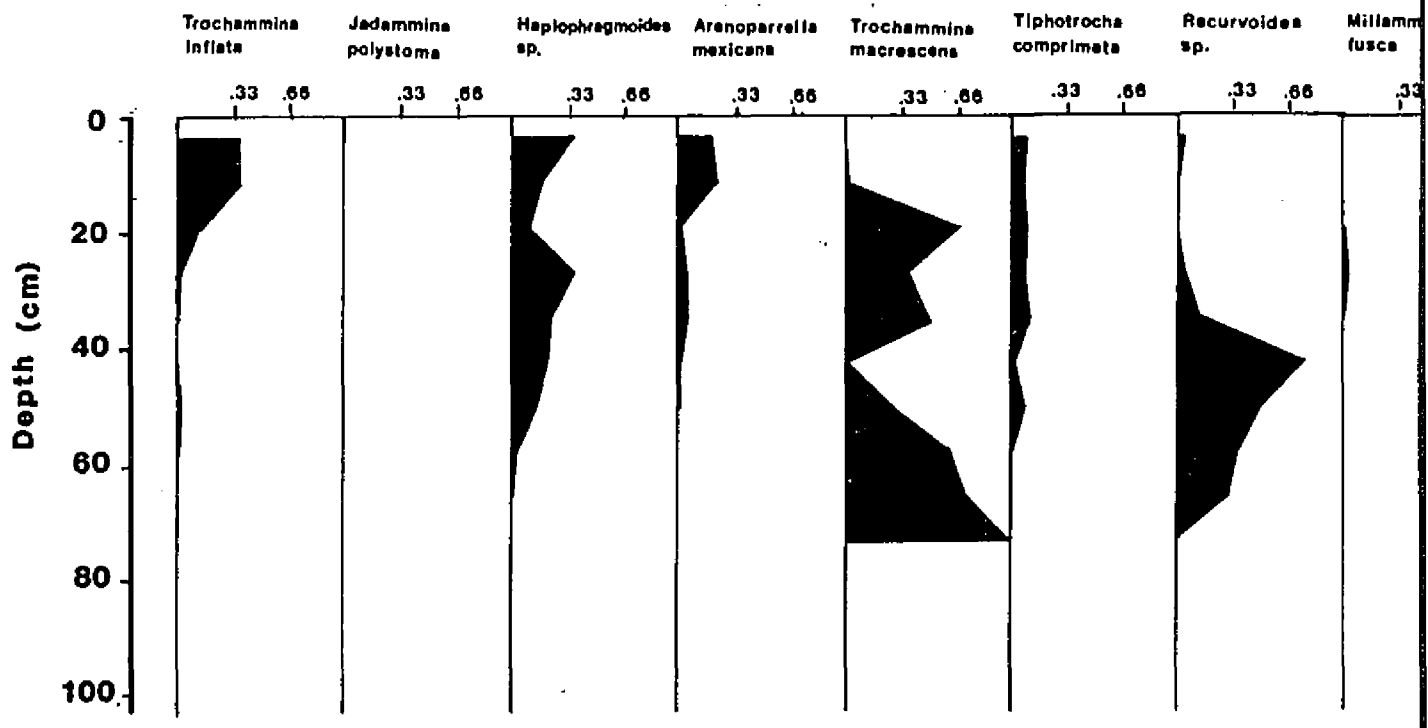
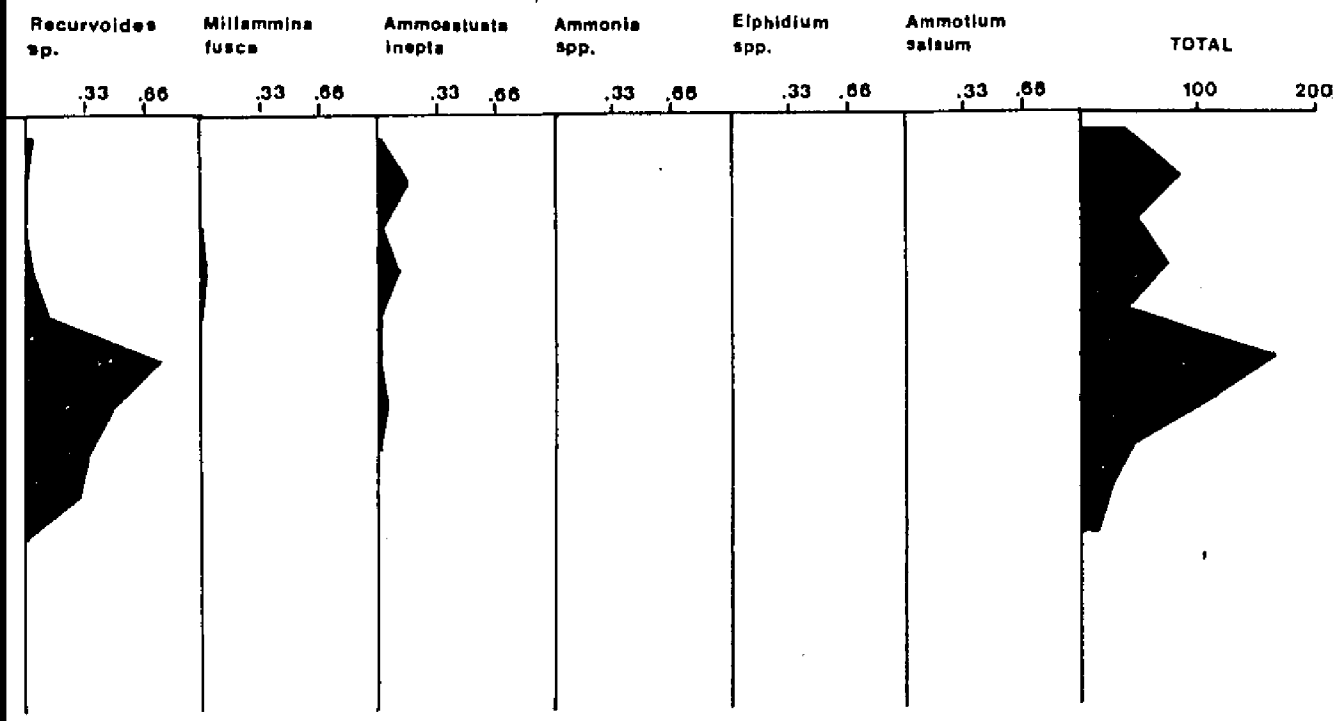


FIGURE 13. Foraminifera Depth Distribution in C



Distribution in Core SM08.

More definitive salinity determinations were achieved by examining the relative abundance of specific taxa. Results relating salinity to species composition from Parker and Athearn (1959) were applied to the foraminifera data in this study. The relative abundance of the more salinity tolerant foraminifera (*Trochammina inflata* and *Jadammina polystoma*) were compared to the relative abundance of the less salinity tolerant foraminifera (*Trochammina marcescens*, *Tiphotrocha comprimata*, *Arenoperella mexicana*, and *Haplophragmoides* sp.). A numerical index of paleosalinity was determined by dividing the relative abundance of the more salinity-tolerant foraminifera by the relative abundance of the less salinity tolerant foraminifera. A salinity index was derived from the following equation:

$$\left(\frac{[T.\ inflata]+[J.\ polystoma]}{[T.\ Marcescens]+[T.\ comprimata]+[A.\ mexicana]+[H.\ sp.]+[T.\ inflata]+[J.\ polystoma]} \right) * 100$$

[ ] denotes relative abundance

High values of the index reflect high salinities. A lower limit of 5 ppt (0 salinity index) is assigned to the basal limit of foraminifera occurrence.

The indices are plotted against depth for each core in Figures 14-16. All three cores exhibited a trend of decreasing salinity as core depth increased, revealing a

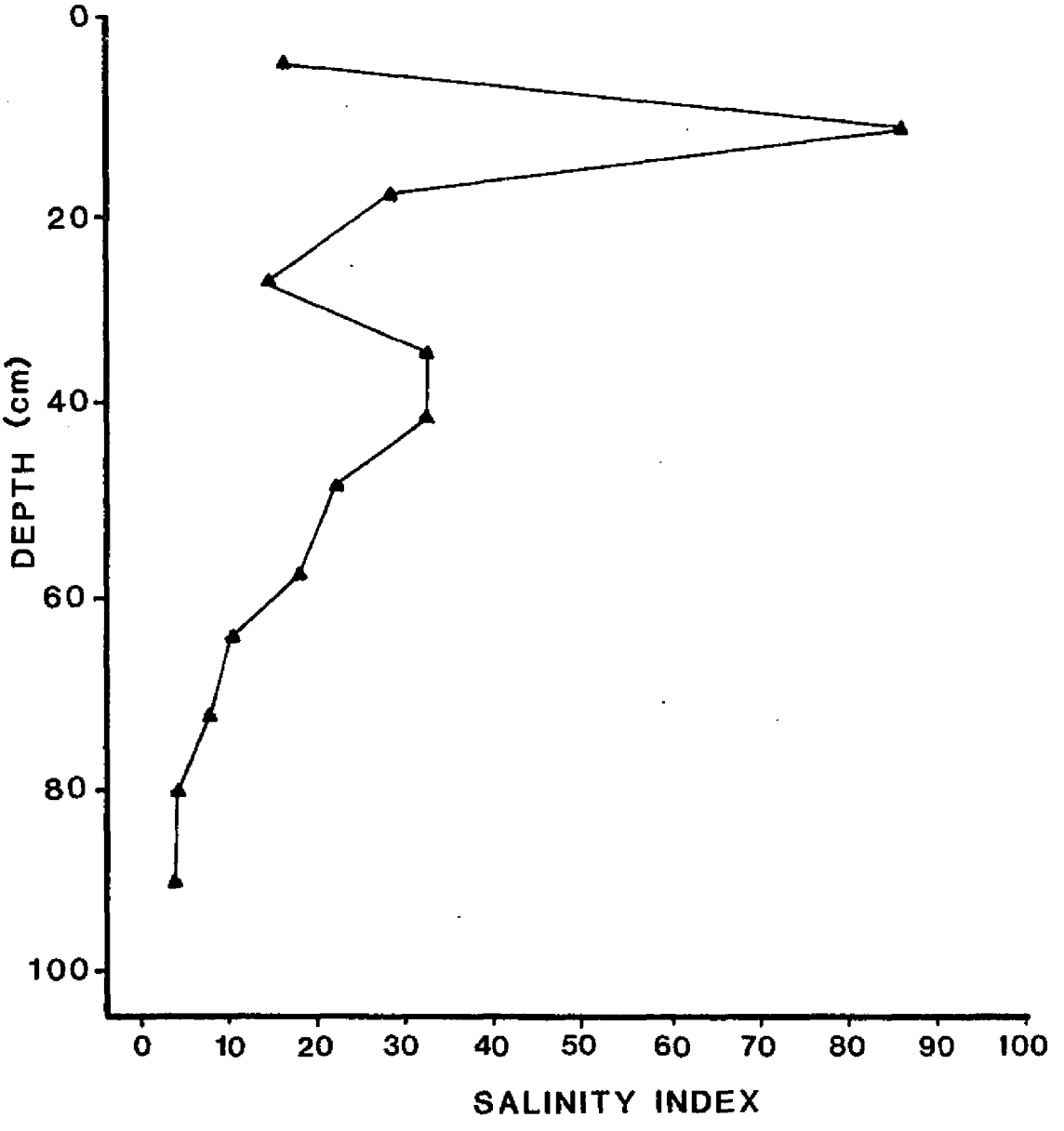


FIGURE 14. Foraminifera Salinity Index vs. Depth in Core SWLA3

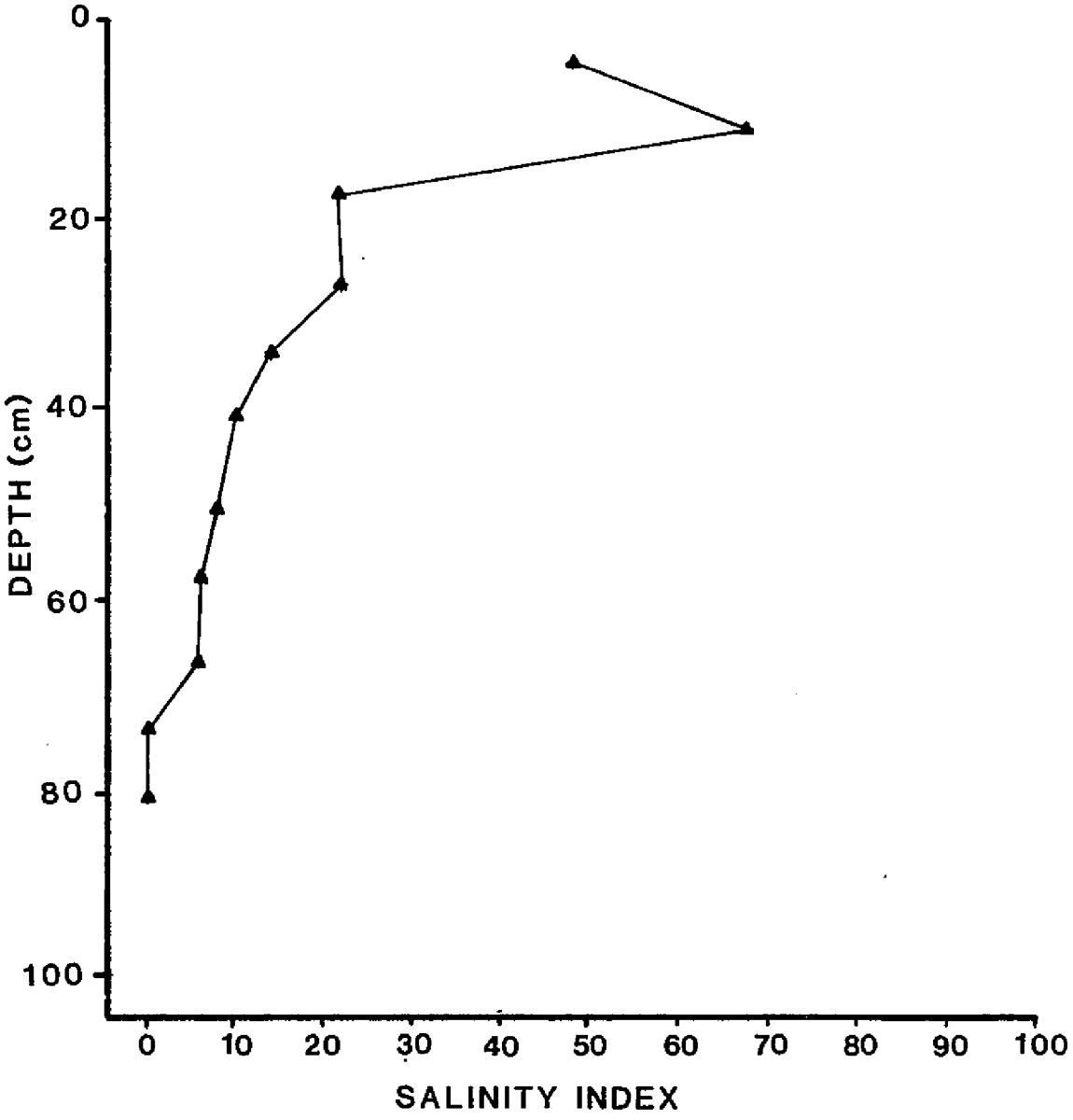


FIGURE 15. Foraminifera Salinity Index vs. Depth In Core SWLA4

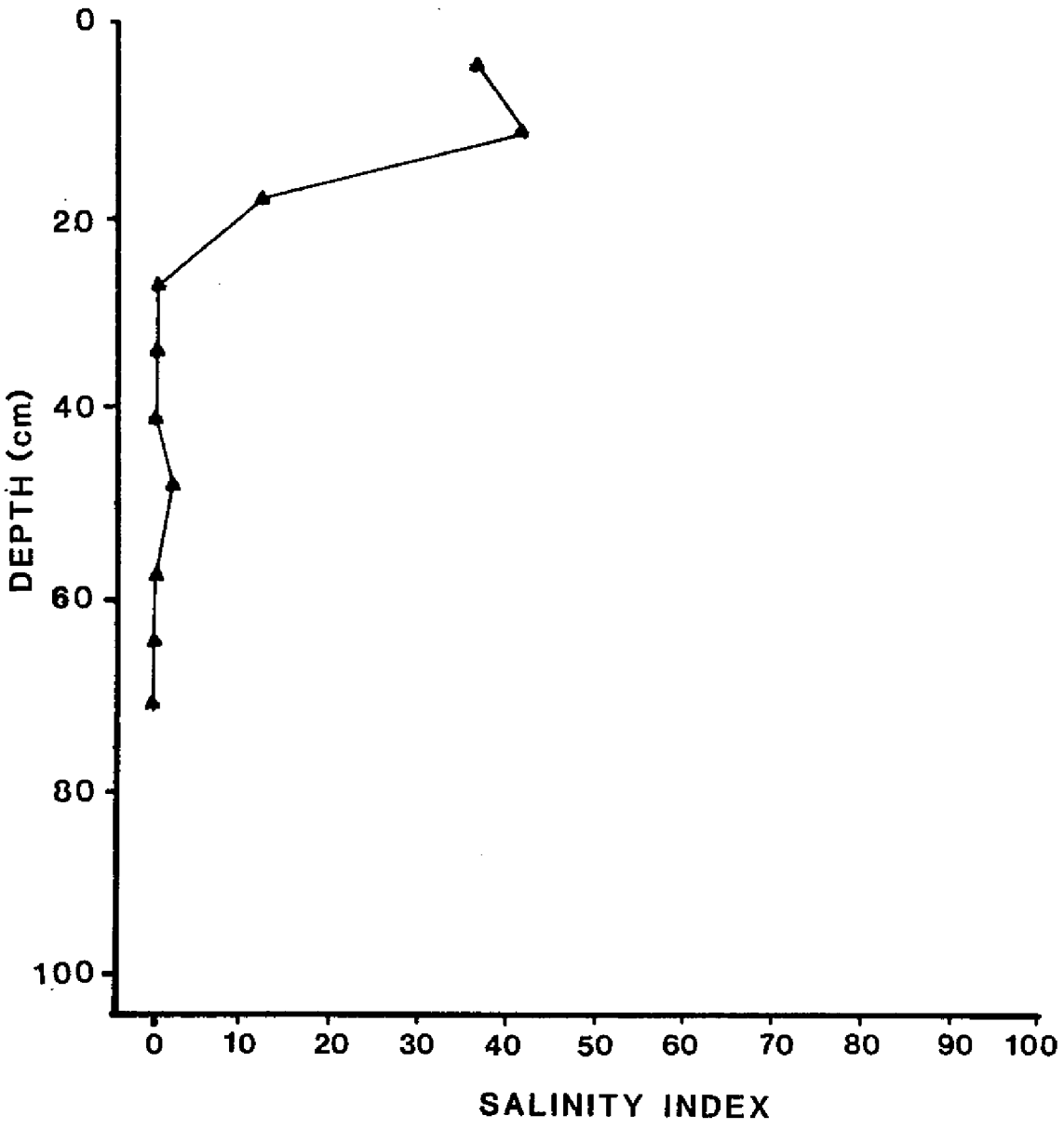


FIGURE 16. Foraminifera Salinity Index vs. Depth in Core SM08

general basinwide salinity increase over time. In addition, maximum paleosalinity of the marsh facies occurred in the intervals between 7.6 to 15.2 cms in each core. This indicates: (1) maximum salinity was achieved at this sub-surface interval and the basin is presently undergoing a salinity decrease, or (2) the sub-surface salinity maximum was an anomalous and transitory event.

The depth of first foraminifera appearance, the increase in salinity, and the sub-surface salinity maximum are common to all cores and can be regarded as general basinwide events. Closer examination of the foraminifera data in each core revealed local variations in depositional environment and salinity history. Results for each core follow.

Core SWLA3

SWLA3 was the only core containing significant numbers of calcareous, hyaline foraminifera. The hyaline foraminifera belong to species of the genera *Ammonia* and *Elphidium* and were continuously present in the interval from 15.2 cm to 76.2 cm. The sediments from which they were encountered were non-peat, organic clays and peaty clays.

Figure 17a depicts the percentage of hyaline foraminifera at each depth. Sediments below 25.4 cm (to a depth of 68.6 cm) predominantly contained hyaline

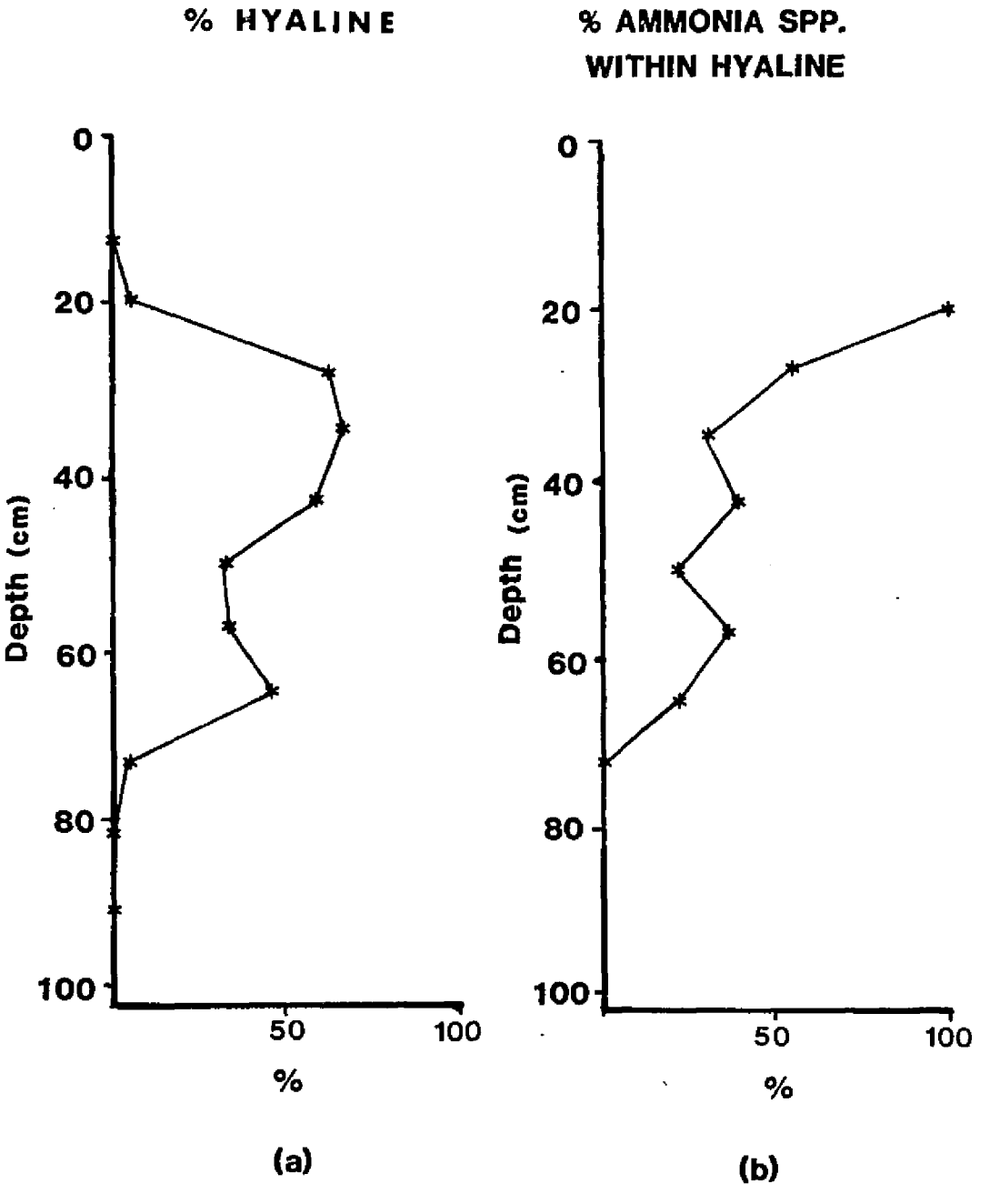


FIGURE 17. Distribution of Hyaline Foraminifera in Core SWLA3.

foraminifera. The environment of deposition during this interval (15.2 to 76.2 cm), based on the foraminifera assemblage, was a brackish-to-saline lake.

Figure 17b is a plot of the percent of *Ammonia spp.* (of the total number of hyaline foraminifera) at each sample depth. Higher proportions of *Ammonia* represent fluctuating salinities and hypersaline events. From the *Ammonia* data in this core, there is evidence of an increase in salinity through time in the lake. The salinity increase could have occurred by two mechanisms: (1) the regional salinity increase that was operative throughout the basin, and (2) infilling of the lake, lowering of water levels, and evaporation.

As the lake became progressively smaller, the locus of deposition moved closer to the fringing marshes. Increasing numbers of marsh agglutinated foraminifera were transported into these lake sediments, resulting in decreasing proportions of hyaline foraminifera. When the lake became completely filled a saline marsh developed (0 to 15.2 cm). The foraminifera in this interval were indicative of a typical, high-salinity marsh assemblage.

Core SWLA4

Foraminifera of core SWLA4 consisted entirely of agglutinated marsh forms. Figure 15 reveals an almost linear increase in the salinity index as depth decreased.

The unique feature of this core is the presence of pseudo-chitonous morphotypes of the species *Trochammina marcescens*. A pseudo-chitonous foraminifera constructs a poorly agglutinated, translucent, organic walled test. Pseudo-chitonous foraminifera are indicative of very low salinities (approximately 5 ppt). Figure 18 shows the proportion of *Trochammina marcescens* having pseudo-chitonous tests for each sample depth. The bottom two samples (69.9 to 85.1 cm) contained a mono-specific population of pseudo-chitonous *T. marcescens*. As depth decreased, (69.9 to 15.2 cm) the proportion of agglutinated forms of *T. marcescens* increased. In addition, other typical agglutinated marsh foraminifera appeared. These data reveal a fluctuating salinity history through time, characterized by frequent periods of low salinity (5 ppt). These low-salinity periods decreased in frequency through time as lower proportions of *T. marcescens* in a pseudo-chitonous state were recovered. The top two samples (0 to 15.2 cm) were totally devoid of pseudo-chitonous *T. marcescens*, indicating higher and more stable salinity conditions.

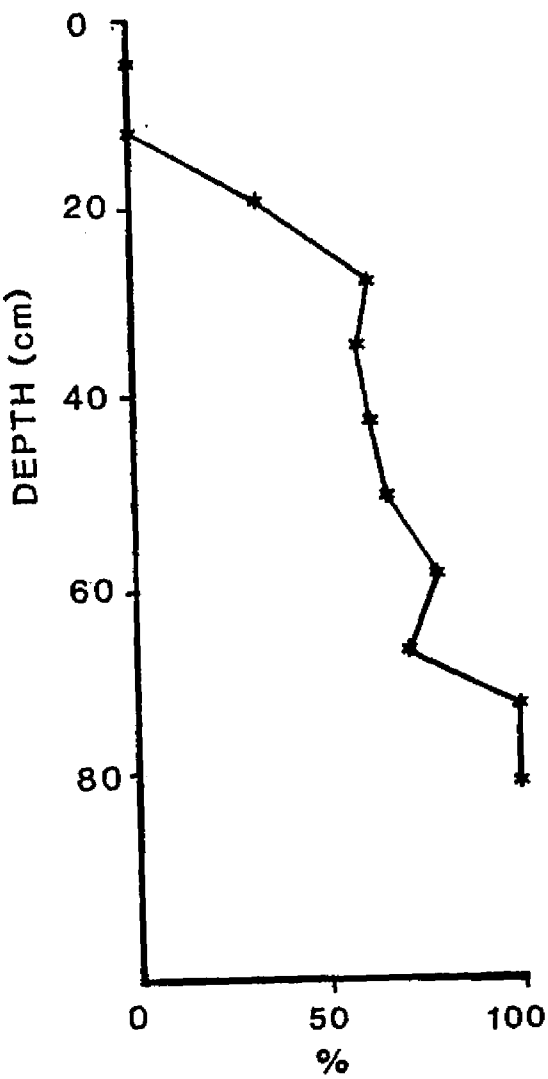


FIGURE 18. Depth Profile of % of *T. macrescens* with Pseudo-chitonous Tests in Core SWLA4

Core SM08

Foraminifera assemblage of core SM08 consisted of a continuous sequence of agglutinated marsh forms.

Examination of Figure 16 reveals low salinity assemblages towards the bottom of the core, and high salinity assemblages towards the surface.

The salinity history derived from the foraminifera data can be summarized as moderately low and constant below 25.4 cm, without the fluctuating and extremely low salinities encountered in core SWLA4. Above 25.4 cm the salinity history of core SM08 was very similar to the histories of the near-surface sediments in cores SWLA4, and SWLA3.

The interval from 38 to 61 cm in core SM08 contained high absolute abundances of *Recurvoides sp*. The occurrence of *Recurvoides sp*. has been recorded in other marsh studies; however, no ecological assessments of their distribution were made.

VII. PALEOSALINITY ANALYSIS - GEMMULES

The gemmule is a reproductive resting stage in fresh and some marine sponges (Simpson and Fell, 1974; Simpson and Gilbert, 1973). Gemmules are small spherical bodies approximately 1 mm in diameter, consisting of small siliceous spicules embedded in an organic matrix. Gemmules are formed in the fall, over winter, and in the spring eject archaeocytes which produce adult sponges.

Poirrier (1969) studied the distribution and ecology of freshwater sponges in Louisiana. This study investigated some of the environmental factors affecting the distribution of several sponge species. Included in this study was a taxonomic discussion of the gemmules, and the salinity limitations of each species.

All freshwater sponge species have a salinity tolerance range (Figure 19). Assuming the distribution of the gemmule parallels the distribution of the parent sponge, the gemmule assemblage of a sediment can be used as a paleosalinity indicator. The range of this paleosalinity indicator is 0 to 6 ppt.

The upper salinity limit of the most saline-tolerant freshwater sponge species in Louisiana coincides with the lower salinity limit of foraminifera. Therefore, a

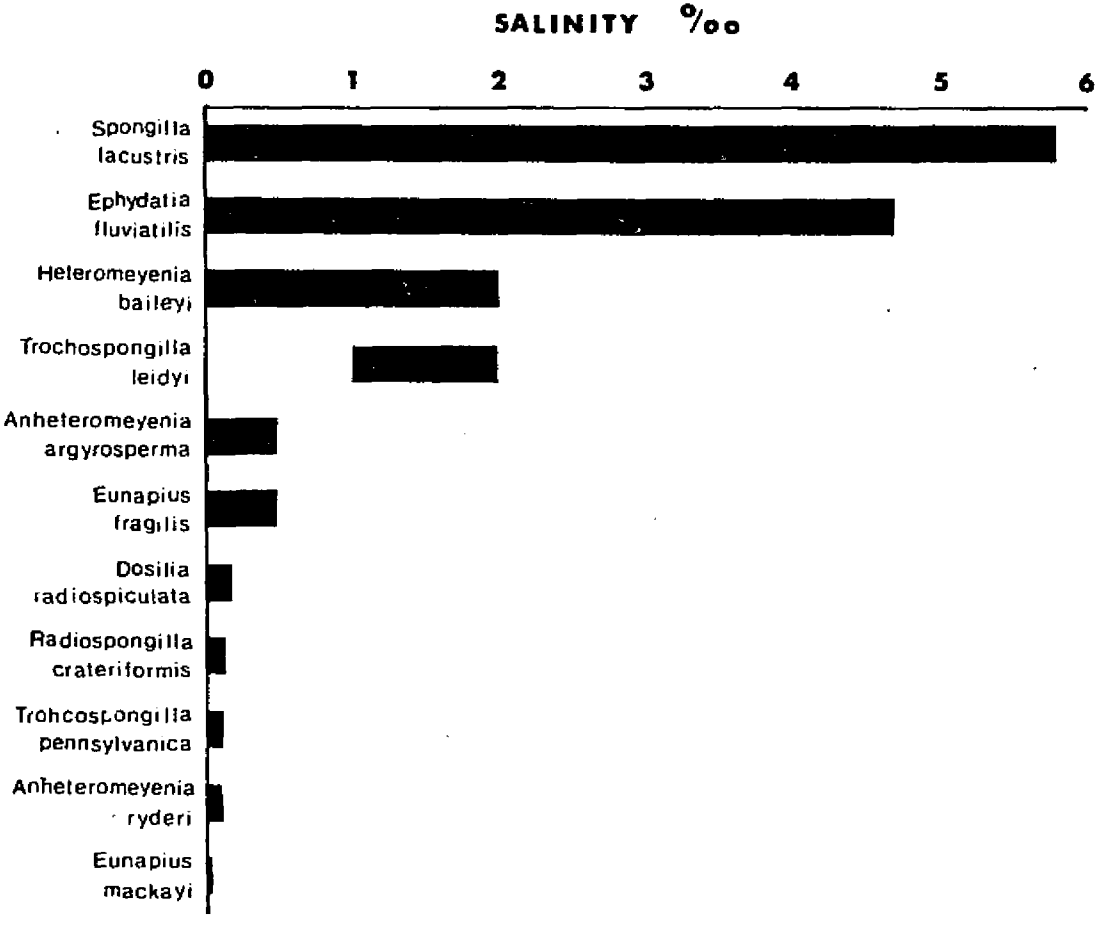


FIGURE 19. Salinity Distribution of Louisiana Fresh Water Sponges.

combination of gemmule and foraminifera analyses as paleosalinity indicators spans the entire salinity range from freshwater to normal marine.

The morphology of the intact gemmule cannot be used to taxonomically identify the sponge species. The organic matrix must be dissolved and the residual siliceous material used for taxonomy. This residual siliceous material consists of gemmoscleres, megascleres, and microscleres. Criteria used for taxonomic identification of the gemmule are size, shape, and types of gemmoscleres, and presence or absence of megascleres and microscleres.

Gemmule analysis was used in this study to elucidate the paleosalinity histories of the oligohaline (< 6 ppt) portions of the cores.

Methods

The gemmules were isolated along with seeds and foraminifera. Sample preparation was covered in the previous section on seed methods. Isolated gemmules from each sample were cemented to a coverslip and digested with hot nitric acid. The nitric acid step dissolved the organic matrix, freeing the siliceous material. Digestion step was repeated until the organic matrix was totally dissolved. A coverslip was carefully cemented to a glass microscope slide using glycerin jelly as the mounting medium.

Observation of the isolated siliceous material was accomplished under transmitted light microscopy (ca. 400X magnification). Microphotographs and descriptions of each gemmule are presented in Appendix III.

Results

Seven gemmule sponge species were encountered in the three study cores. The species, in order of decreasing salinity tolerance, were *Spongilla lacustris*, *Ephydatia fluviatalis*, *Heteromeyenia baileyi*, *Anheteromeyenia argyrosperma*, *Dosilia radiospiculata*, *Radiospongilla crateriformis*, and *Anheteromeyenia ryderi*.

The gemmules were generally encountered in the lower half of each core. Figures 20-22 illustrate the depth distribution of each species, plotted as relative abundance, for cores SWLA3, SWLA4, and SM08. The total number of gemmules recovered from each sampling interval is also tabulated.

The maximum paleosalinity in each sample interval was derived from the upper salinity limit of the least salinity-tolerant species present. For example, the presence of high salinity-tolerant sponge gemmules in conjunction with the absence of salinity-intolerant species indicated relatively high salinity (~ 6 ppt). Conversely, the presence of both salinity-tolerant and intolerant

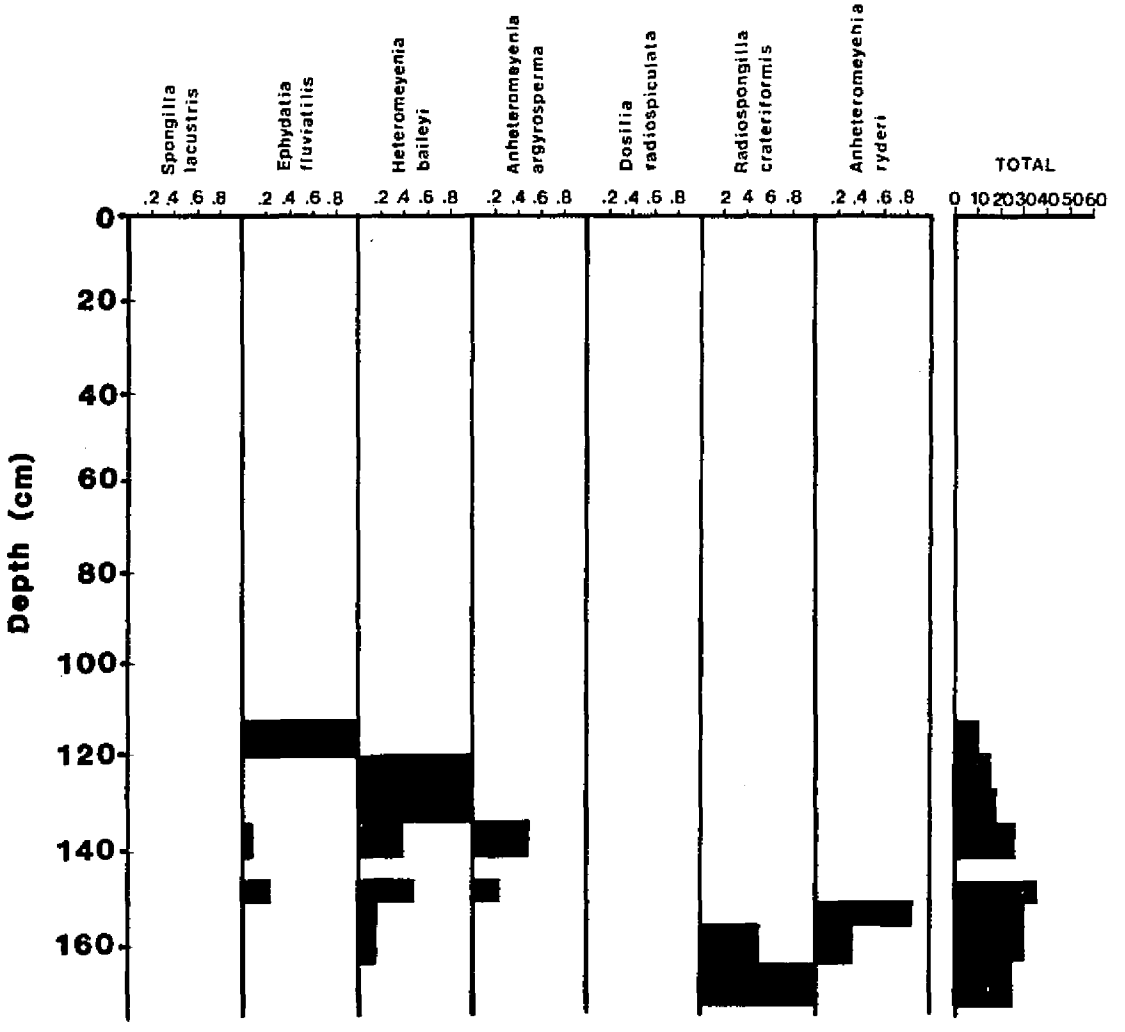


FIGURE 20. Depth Distribution of Gemmules in Core SWLA3.

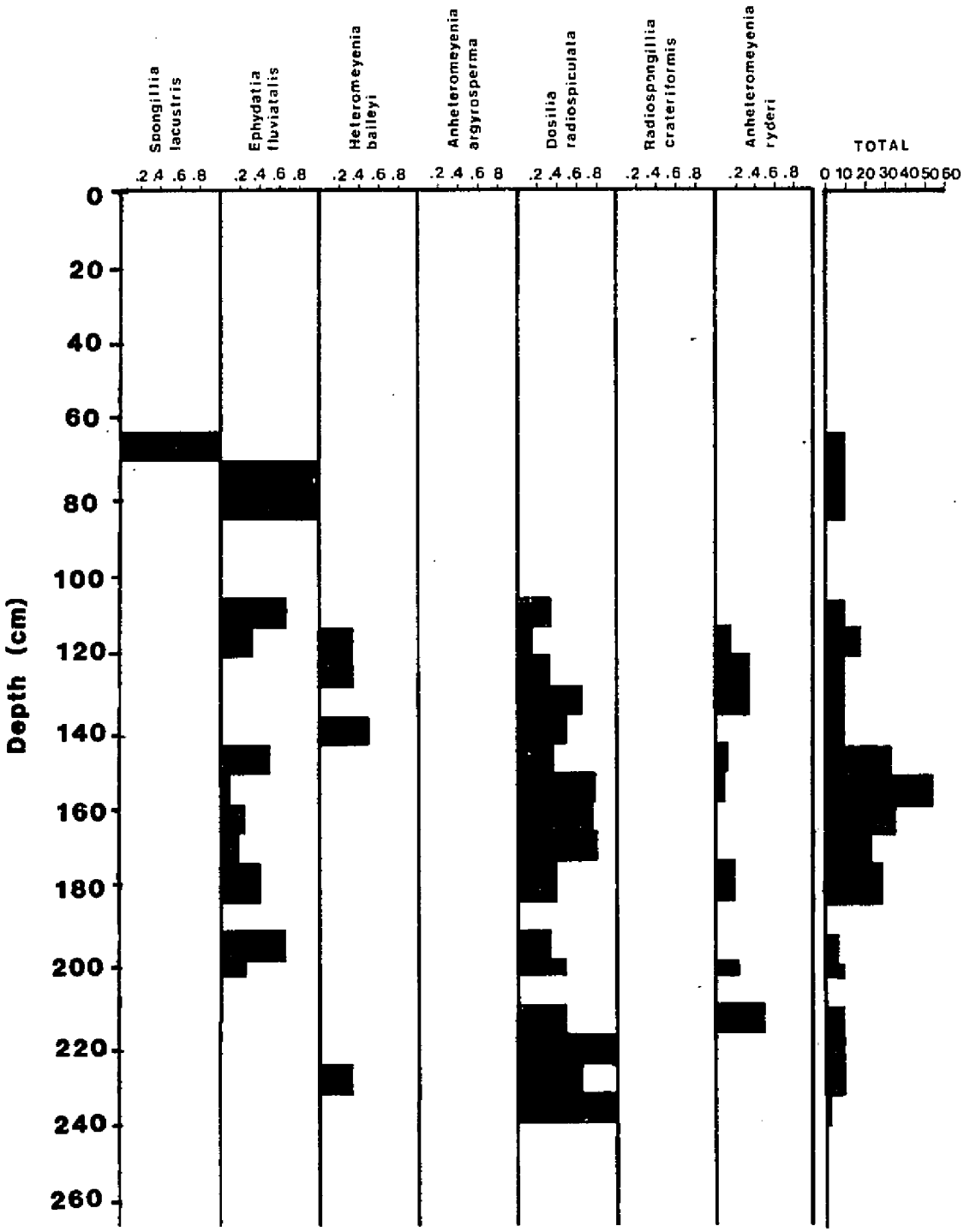


FIGURE 21. Depth Distribution of Gemmules in Core SWLA4.

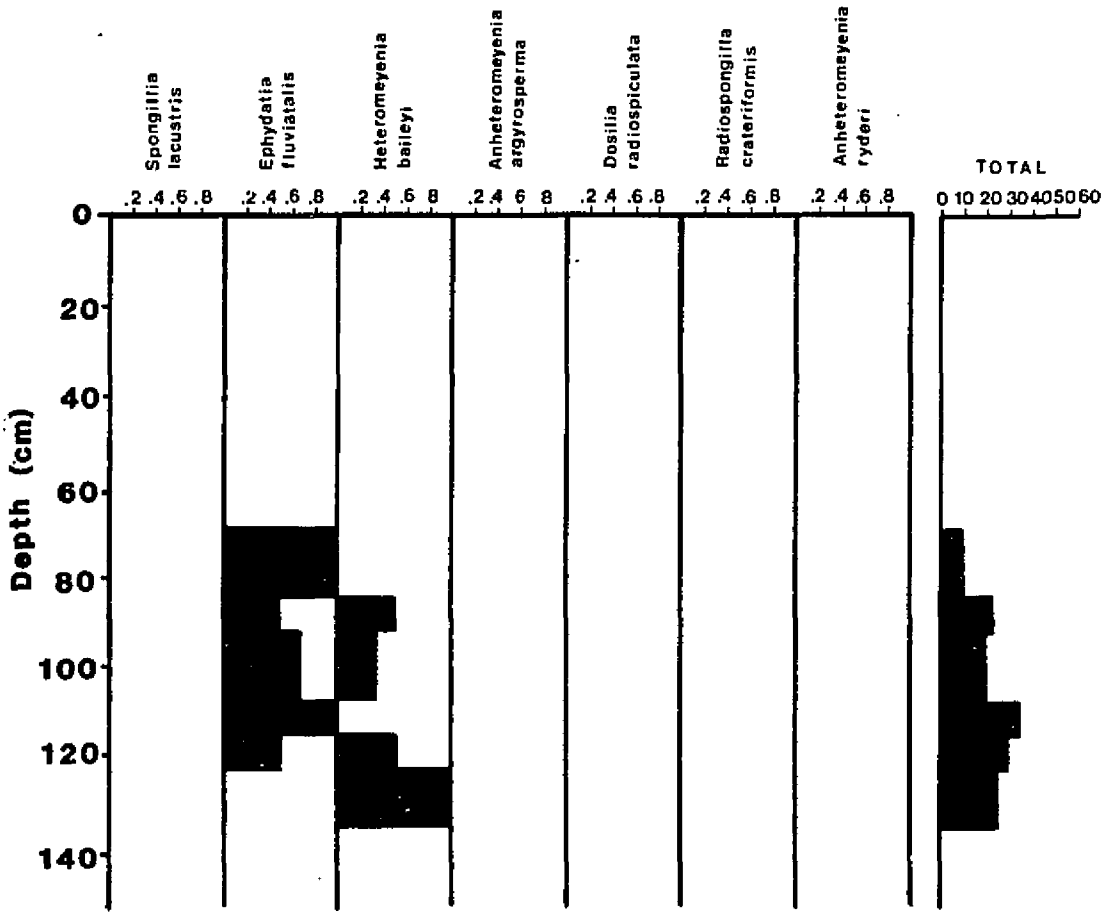


FIGURE 22. Depth Distribution of Gemmules in Core SM08.

species indicated fresh conditions. Therefore, maximum salinity for each sample was dependent on the upper salinity tolerance of the most oligohaline species in that sample.

An analysis of the gemmule distribution and salinity interpretation for the cores follow.

Core SWLA3

Five species of sponge gemmules were encountered in core SWLA3: *Ephydatia fluviatalis*, *Heteromeyenia baiyeli*, *Anheteromeyenia argyrosperma*, *Radiospongilla crateriformis*, and *Anheteromeyenia ryderi*.

The first appearance of gemmules occurred in the sample interval from 112 to 119 cm, containing a monospecific population of *E. fluviatalis*. The salinity during this time interval was between 2 and 5 ppt.

From 119 to 135 cm the gemmule population consisted of *H. baileyi*. Salinities during this interval were between 1 and 2 ppt.

Three species, *E. fluviatalis*, *H. baileyi*, and *A. argyrosperma*, dominated the gemmule assemblage in the intervals 135 to 142 cm, and 147 to 152 cm. The maximum paleosalinity, as determined by the upper salinity tolerance of *A. argyrosperma*, was .5 ppt.

Totally fresh conditions prevailed during the depositional interval from 152 to 175 cm, due to the presence of salinity-intolerant gemmules (*R. crateriformis* and *A. ryderi*).

The paleosalinity history of the oligohaline portion of core SWLA3 is characterized by a steady and gradual increase in salinity through time. The salinity increased from fresh conditions at the base of the core, to between 2 and 5 ppt at the top of the oligohaline section (112 cm).

Core SWLA4

The gemmule assemblages in core SWLA4 were divided into two zones. An upper zone, between 62 to 85 cm, contained high salinity-tolerant gemmules (*Spongilla lacustris* and *Ephydatia fluviatalis*). The second zone extended from 105 to 234 cm, containing salinity tolerant and intolerant species (*E. fluviatalis*, *H. baileyi*, *D. radiospiculata*, and *A. ryderi*). The two zones were separated by a 20 cm interval devoid of gemmules.

The first appearance of gemmules in the upper zone (62 to 70 cm) consisted of a monospecific occurrence of *S. lacustris*. *S. lacustris* can tolerate salinities up to 6 ppt. The remainder of the upper zone (70 to 85 cm) contained a monospecific population of *E. fluviatalis*. The three sample intervals constituting the upper zone

overlapped with the lower three sample intervals of foraminifera occurrence. Furthermore, pseudo-chitonous morphotypes of *Trochammina marcescens* dominated the foraminifera assemblages. The occurrence of *S. lacustris* and *E. fluviatalis* in the upper zone, in conjunction with the presence of foraminifera, indicate salinities between 5 and 6 ppt.

The lower zone (105 to 234 cm) contained gemmule assemblages with both salinity-tolerant (*E. fluviatalis* and *H. baiyeli*) and salinity-intolerant (*D. radiospiculata* and *A. ryderi*) species. The paleosalinity during this depositional phase was totally fresh due to the presence of the salinity intolerant species.

The salinity history of the oligohaline portion of core SWLA4 can be summarized as relatively high in the upper zone (5 to 6 ppt), and totally fresh in the lower zone.

Core SM08

Two species of freshwater sponge gemmules were encountered in core SM08. *Ephydatia fluviatalis* first appeared at a depth of 68.6 cm. The *E. fluviatalis* zone continued to a dpth of 83.8 cm. Since the maximum salinity tolerance of *E. fluviatalis* is 5 ppt, and due to the absence of lower salinity tolerant species, the paleosalinity during this interval was between 2 and 5 ppt. Additionally, the

deepest sample interval containing foraminifera overlapped with the first appearance of *E. fluviatalis* at 68.6 to 76.2 cm. This trend further confirms salinities approximating 5 ppt in the *E. fluviatalis* zone.

At 83.8 cm, and continuing to 137.2 cm, the gemmule assemblage consisted of *E. fluviatalis* and *H. baiyeli*. The presence of *H. baiyeli* and the absence of lower salinity-tolerant species indicate that salinities were between 1 and 2 ppt.

In review, the gemmule data for core SM08 reveal stable and slightly brackish conditions during the depositional history of the lower half of the core. Totally fresh conditions did not exist during any phase of the depositional history represented by the core material.

VIII. MACERAL ANALYSIS

A maceral is defined as an acid-resistant, organic particle dispersed in sedimentary rocks. Maceral analysis is the quantitative study of the type, degradation, and color of these organic particles as a means of determining environment of deposition, diagenesis, and thermal history of a sedimentary rock.

Organic matter in sedimentary rocks consists of the variably degraded remnants of allocthonous and autocthonous organic compounds. The majority of the preserved organic matter is non-particulate, consisting of high molecular weight compounds derived from biological and chemical degradation. The subordinate organic fraction is particulate and consists of cellular remnants and products of degradation. The study of these organic particles (macerals) in sedimentary deposits is a powerful method for determining the origin of sedimentary organic matter.

Microscopic characterization of particulate organic matter is widely used for the classification of coal (Stach et al., 1975; Spackman, 1958; Spackman and Thompson, 1964). The classification scheme is based on the degree of light reflectivity of polished macerals. Exinites are the least reflective macerals, represented by hydrogen rich spores,

algae, higher plant waxes, cuticles, and resins. Inertinite is the most highly reflecting maceral, consisting of carbonized, non-reactive products of higher plants. The most common maceral in coals is vitrinite, exhibiting reflectances between exinite and inertinite. Vitrinite originates from the cellular contents and degradation products of higher plants.

Studies of the particulate organic fraction have been applied to a wide variety of sedimentary rocks in addition to coals. Petroleum geologists utilize visual kerogen analyses to determine petroleum source rock potential (Staplin, 1969; Burgess, 1974; Bujak et al., 1977; Alpern, 1970; and Teichmuller, 1971).

Major shortcomings exist in the application of coal petrography and visual kerogen methods to paleoenvironmental analyses. Organic matter classification of the particulate fraction should utilize categories indexed to the degree of microbial and chemical degradation. The degree of organic decomposition can then be used as a criterion for recognizing depositional environments. Maceral analysis (Hart, 1979b) meets the above criteria.

Maceral analysis classifies each maceral by three parameters: (1) genetic origin, (2) degree of degradation, and (3) color. Genetic origin refers to the biological source of the maceral (i.e., higher plant, algal, fungal,

or bacterial). Degradation state is an assessment of type and extent of chemical and/or biological alteration. Color of the maceral is an important parameter for determining thermal history and recycling.

Maceral analyses have been used to solve a variety of geological problems. Hart (1979a) used maceral analysis to study and classify the environments of deposition within the modern Mississippi delta.

Maceral analysis is particularly helpful in studying organic lean sedimets containing impoverished palynomorph assemblages. Wrenn and Beckman (1981a) applied maceral analysis to a sedimentary sequence of core recovered from Taylor Valley, Antarctica. The 200 meters of Pliocene-Pleistocene glacial sediments were low in organic matter and markedly devoid of conventional fossils. Utilizing maceral and total organic carbon (T.O.C.) analyses, the authors demonstrated a recycled, higher plant terrestrial origin for the organic matter. Autocthonous organic deposition of algal matter occurred at two discrete depths in the sedimentary sequence implying transitory, in situ, glacial-lacustrine environments.

The maceral assemblage of a sedimentary rock reveals information regarding the physio-chemical environment of deposition. Wrenn and Beckman (1981b,1982) applied maceral and T.O.C. analyses to a study of a composite 90 cm core

from mid-Miocene glacial marine sediments underlying the Ross Ice Shelf, Antarctica. The sedimentary sequence was divided into upper and lower units based on sedimentology. No significant differences in the maceral assemblages between the two units were evident, except for lower abundances of the amorphous infested indeterminate (A.I.I.) maceral group in the upper unit. The A.I.I. maceral is highly degraded, possibly consisting of particulate humate compounds or aggregates of colloidal organic matter. Absence of these macerals in the upper unit, in conjunction with lower T.O.C. values, indicated that oxidizing conditions destroyed the labile A.A.I. maceral fraction.

Maceral analysis is particularly applicable to the study and classification of peats. Peats contain predominantly autocthonous higher plant organic matter deposited in anoxic to slightly oxic sediments. Phytoclasts (higher plant-derived particles) contain structural and protective elements such as lignin, waxes, suberin, and cuticle. When plant remains are deposited in anoxic sediments, incomplete degradation results. Partially degraded macerals can be used to elucidate certain environmental conditions in the sediments. Furthermore, edaphic factors such as salinity, water depth, and hydrologic regime also affect the maceral assemblage of a sediment.

Maceral analyses of peats and associated sediments in this study were used for two purposes: (1) The maceral assemblage was used to gain insight into some mechanisms of organic matter accumulation for each environment. (2) The maceral assemblage was used as a fingerprint for recognizing and classifying sedimentary environments.

Methods and Classification

Methods

Macerals were isolated and concentrated by acid digestion of peat and sediment samples from the three study cores. Approximately 10 grams (wet weight) were sieved (60 mesh sieve) to remove macro-organic plant material. The fine fraction was then subjected to acid digestion in concentrated HCl for 24 hours. The acid was then decanted and the residue washed with distilled water. Siliceous clastics were destroyed by digestion in 48% HF acid for four days. The acid was subsequently decanted, followed by three rinses with distilled water. The residual organic matter (kerogen) was sieved through a 10u screen to remove small (<10u) particles and clay which interfere with the identification process. Two microscopic slide preparations were made utilizing the greater than 10u kerogen fraction. Sixty macerals were counted and classified on each slide (120 macerals per sample), and recorded on a coding sheet

(Figure 23). Transmitted light microscopic techniques were used to identify the macerals.

Maceral Classification

The initial step in the classification of a maceral was to determine its genetic origin. Higher plant fragments were classified as phytoclasts, algae and algal products as protistoclasts, and bacteria or fungal remains as scleratoclasts. In addition, well preserved palynomorphs were classified into their respective categories (miospores, dinocysts, microforams, or acritarchs). The amorphous infested indeterminate category is a special class for macerals of a genetically indeterminate nature due to extreme biological or chemical degradation. Inertinite macerals are opaque, carbonized remnants of higher plant origin.

The second parameter used to classify the maceral was the degree of degradation by chemical and or microbial processes. Tables II and III are summaries of the visual criteria necessary for recognizing and interpreting maceral degradation states.

The color of the maceral was the third classification measurement. The color of certain macerals (spores and cuticles) reflects the degree of thermal alteration of the

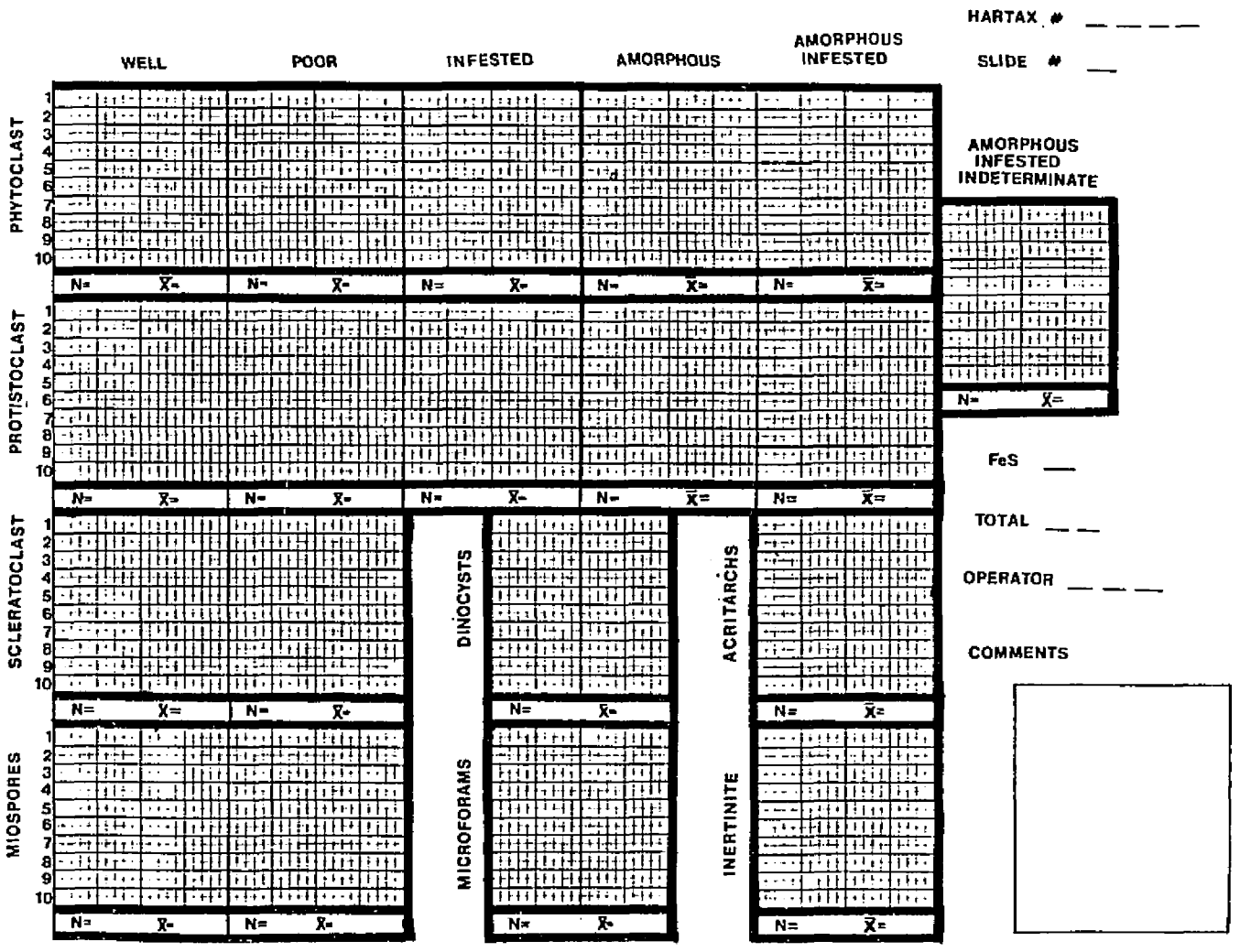


FIGURE 23. Maceral Coding Sheet.

TABLE II. PHYTOCLAST DEGRADATION STATES

DEGRADATION STATE	MORPHOLOGY	INTERPRETATION
Well Preserved	Angular in outline. No evidence of fungal, bacterial, or chemical attack. Cell walls are intact.	Resistant plant fragments such as cuticle or undegraded ligno-cellulose matter. Macerals are either resistant to decay or have escaped biodegradation.
Poorly Preserved	Angular in outline. Minor evidence of fungal and/or bacterial attack.	Plant fragments are similar in origin to the well preserved state except for incipient attack by fungi and/or bacteria.
Infested	Angular in outline. Fungal attack is extensive, especially within cell walls. Some bacterial attack may be evident.	Indicative of biodegradation under oxidative conditions due to the presence of fungal hyphae.
Amorphous Structured	Angular in outline. Cell contents are amorphous. Cell walls are present and intact. No evidence of fungal or bacterial attack.	Absence of microbiological activity may indicate degradation by chemical pathways. Maceral may become resistant to further degradation.
Amorphous Unstructured	Angular in outline. Cell contents are amorphous and cell walls are absent. No evidence of fungal or bacterial attack.	Similar interpretation as the amorphous structured maceral except for the absence of cell walls. Some amorphous unstructured phytoclasts appear resinous.
Amorphous Infested	Angular to fluffy in outline. Cell contents are amorphous with significant bacterial pitting and some fungal infestation.	Moderate to extreme degradation via chemical and/or microbial pathways. Some cells may be filled with precipitated organic debris.

TABLE III. PROTISTOCLAST AND A.I.I. DEGRADATION STATES

PROTISTOCLAST

DEGRADATION STATE	MORPHOLOGY	INTERPRETATION
Well Preserved	Recognizable algal remains with no apparent degradation.	Preserved colonial algae and non-colonial algae bodies and cysts such as dinocysts, acritarchs, Botyrococus, and Tasminites.
Poorly Preserved	Recognizable algal remains with slight infestation by fungi and/or bacteria.	Same as well preserved state. Indication of some attack by fungi and/or bacteria.
Amorphous	Fluffy, cloudlike appearance. Completely amorphous with occasional preservation of a cell wall. Bacterial pitting sometimes evident.	Most common form of algal preservation. Often associated with intense bacterial degradation. Lack of structurally resistant elements allows chemical and biological degradation to produce an amorphous particle.

AMORPHOUS INFESTED INDETERMINATE

Amorphous Infested Indeterminate	Totally amorphous with evidence of chemical, bacterial, or fungal attack.	Several possible origins: 1) exterme microbial and/or chemical degradation of either phytoclasts or protistoclasts. 2) precipitation of humate compunds. 3) fecal pellets.

sediment during its burial history (Gray and Boucot, 1975). In Recent sediments, maceral color can be used to recognize recycled organic input. The thermal alteration index used in this study is based on a ten-point color scale. The color scale, in order of increasing thermal alteration, is:

1	clear	6	bright orange
2	pale yellow	7	orange brown
3	bright yellow	8	brown
4	yellow orange	9	brown black
5	orange	10	black

Results

Results of the maceral analysis for each core are plotted in Figures 24, 25, and 26. The figures depict the relative abundance of each maceral type plotted against depth.

Eleven maceral types were encountered in the core samples. The predominant maceral type in most of the samples was the phytoclasts. Phytoclast degradation ranged from well preserved to the highly degraded amorphous infested. The amorphous infested indeterminate macerals were the second most abundant type, followed by the scleratoclasts, amorphous protistoclasts, and miospores. Inertinite was relatively low and variable throughout the

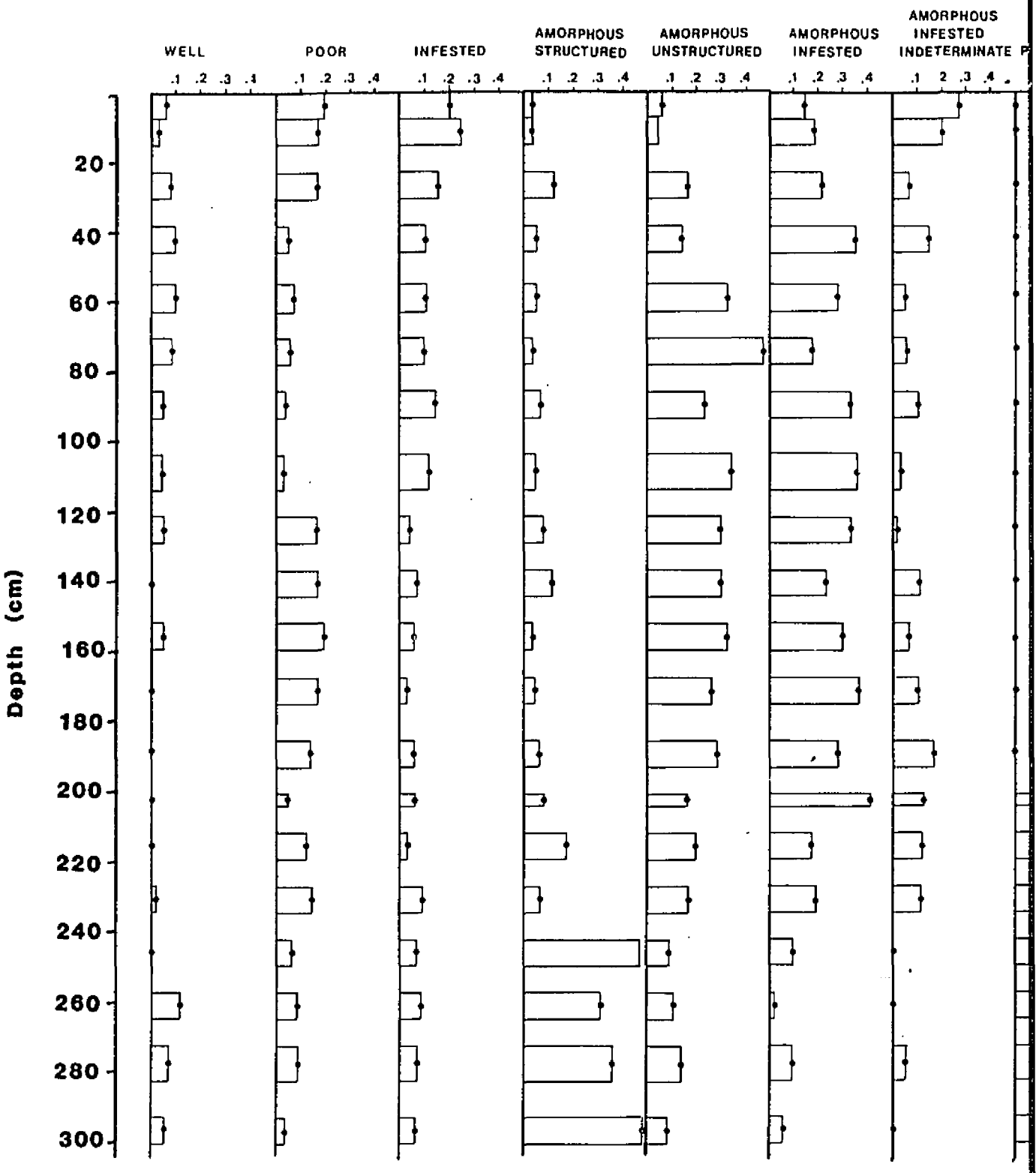
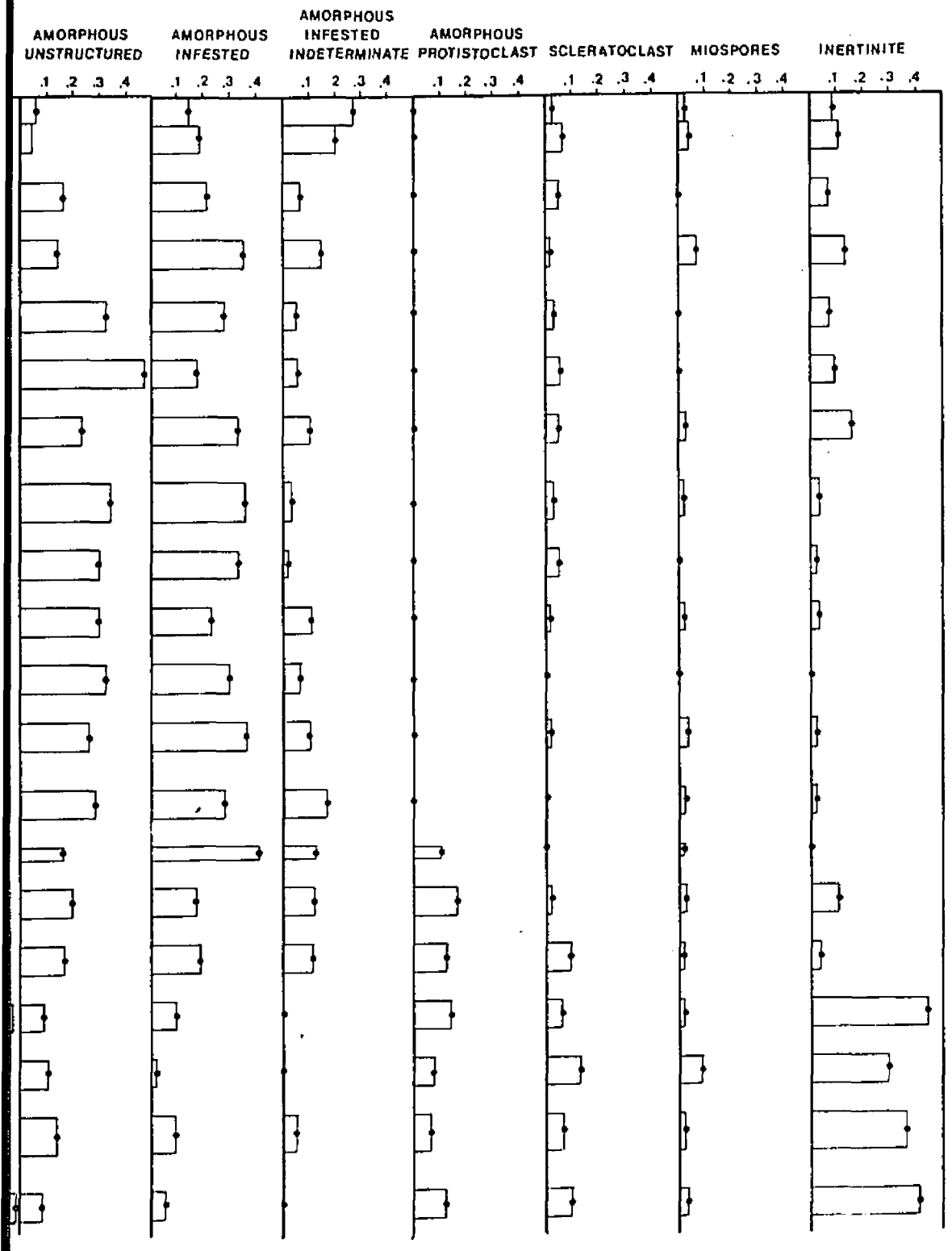


FIGURE 24. Depth Profile of the Relative Abundance of Macera



lative Abundance of Maceral Types in Core SWLA4.

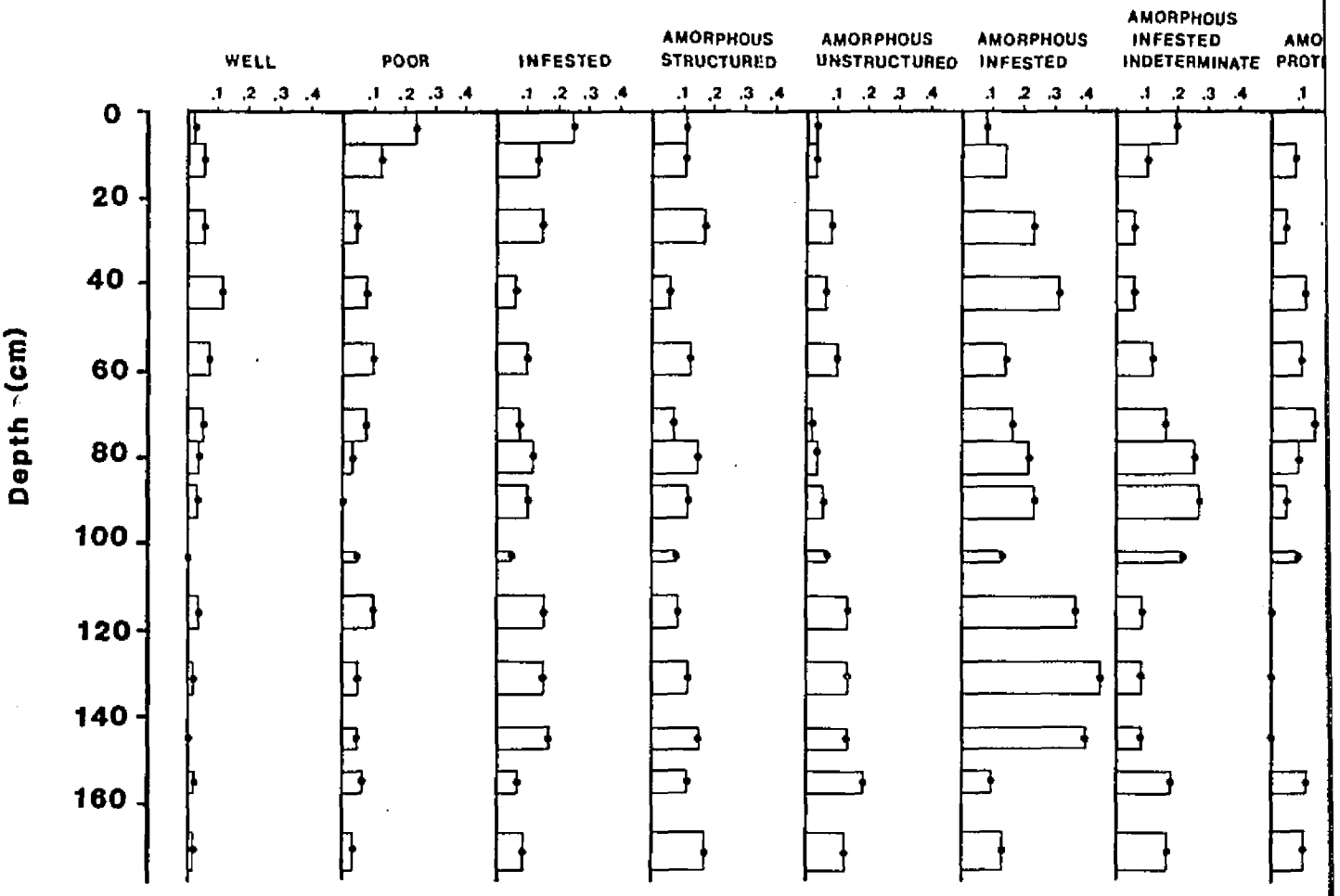
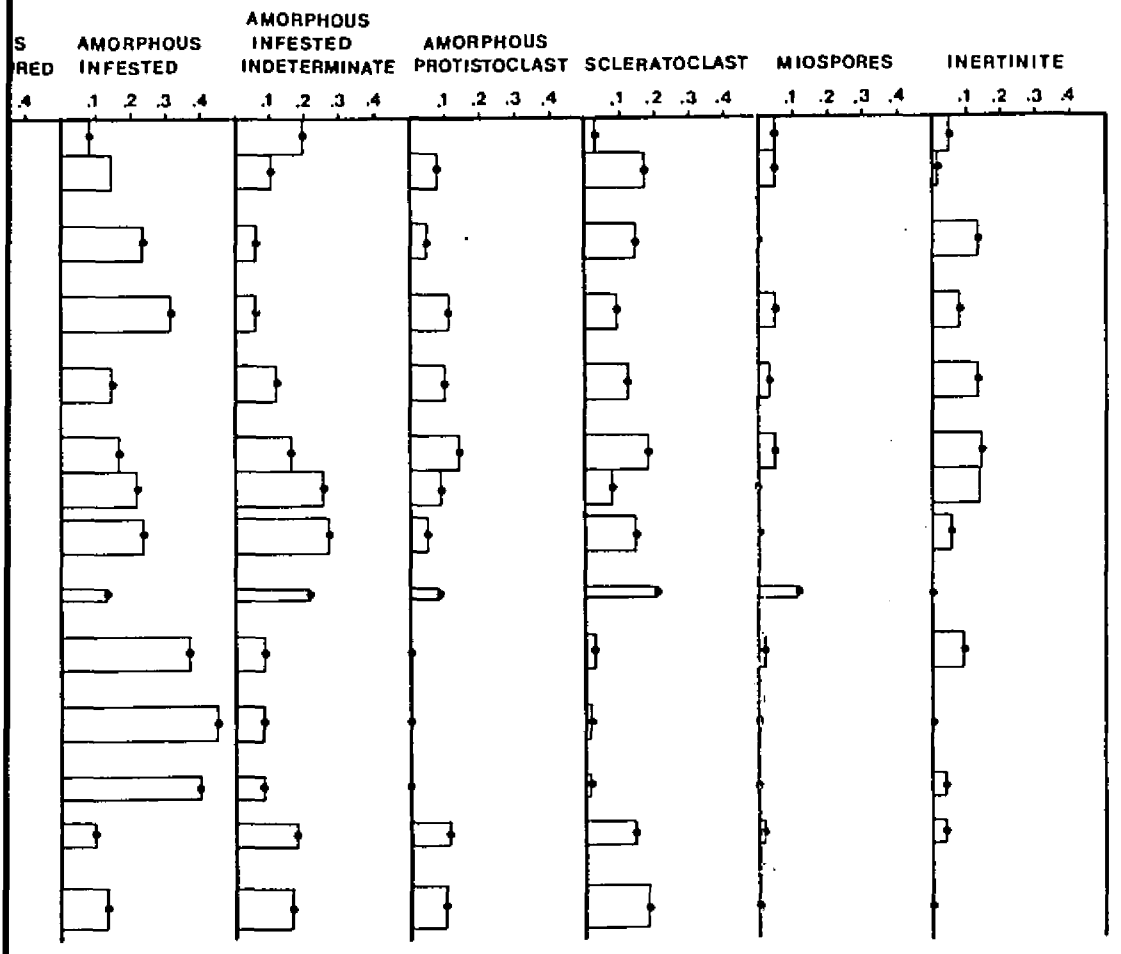


FIGURE 25. Depth Profile of the Relative Abundance of Mace



tive Abundance of Maceral Types in Core SWLA3.

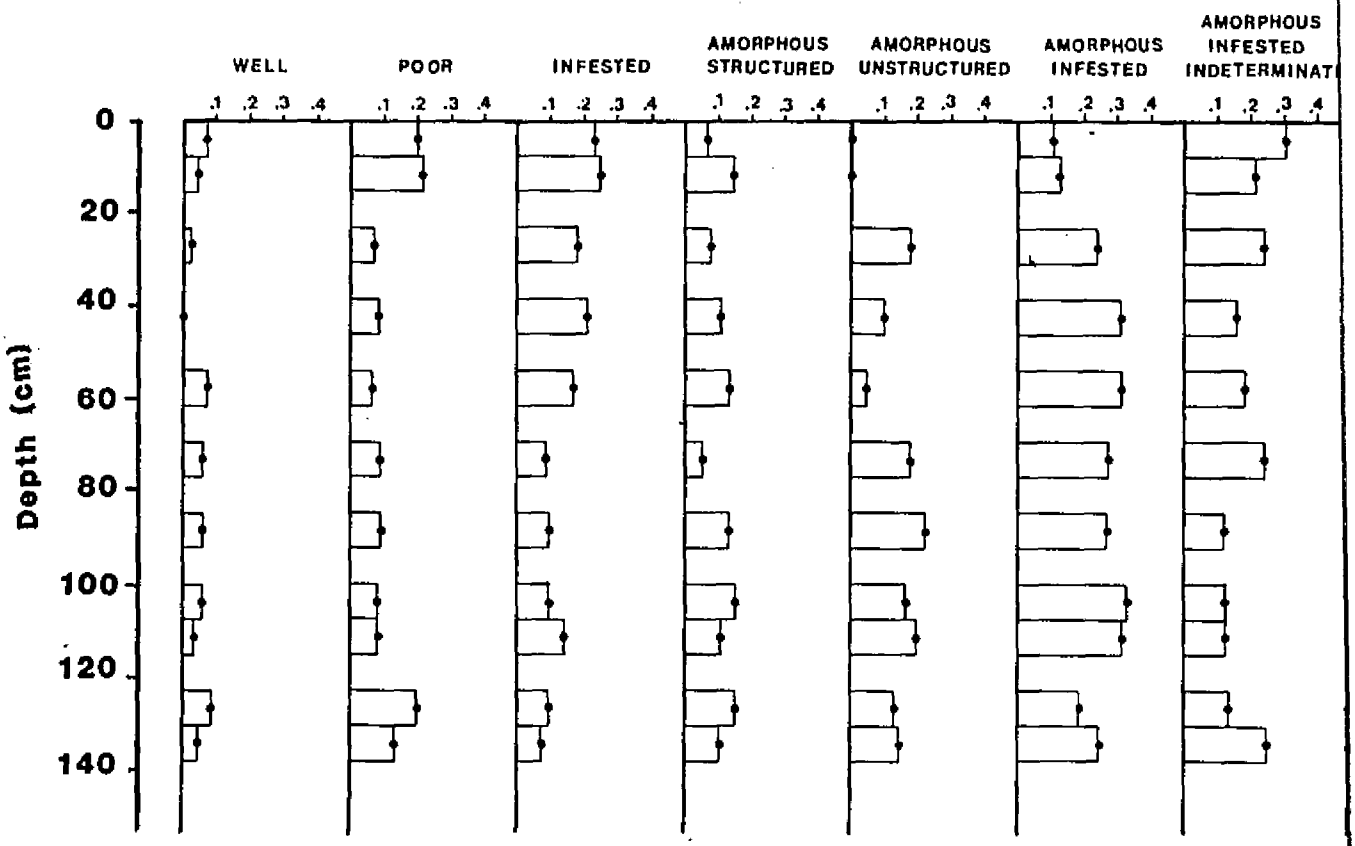
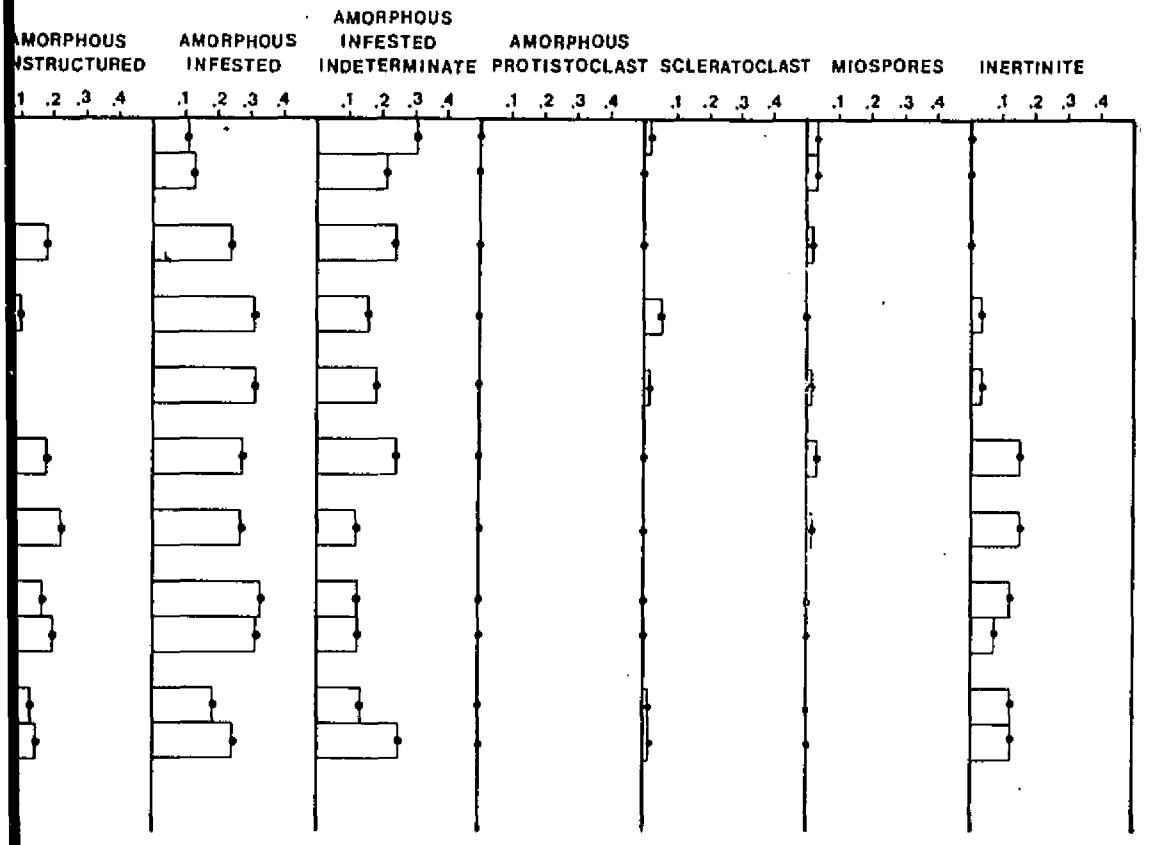


FIGURE 26. Depth Profile of the Relative Abundance of Ma



elative Abundance of Maceral Types in Core SM08.

cores, however, locally high relative abundances of inertinite were encountered in the basal section of core SWLA4.

Photographs of the major maceral types encountered in the study cores are presented in Plates I to IV.

Statistical Analysis

A Q-mode cluster analysis was performed on the maceral data from the three study cores. The purpose was to classify each sample into a group that could be related to the paleoenvironments derived from the fossil analyses. In addition, the cluster analysis elucidated the degree of similarity between the maceral-derived groupings. The maceral-derived groupings can then be used in future studies to identify and classify paleoenvironments. Furthermore, the maceral distribution within the paleoenvironmental clusters revealed mechanisms of organic matter sedimentation and preservation in the marsh and associated environments.

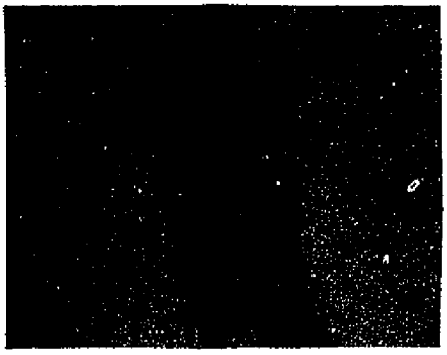
The Q-mode cluster analysis produced seven clusters. The samples in each cluster correlated with the paleoenvironmental categories derived from the fossil techniques. The marsh series consisted of four clusters: (1) saline marsh (2) intermediate and brackish marsh (3) fresh marsh (core SWLA3), and (4) fresh marsh (core SWLA4). The

Plate I. Well and poorly preserved phytoclasts.

a,b,c - Well preserved phytoclasts. These macerals do not exhibit significant microbial or chemical degradation. Note the undegraded cell walls and cellular material in (a); (b) is an example of resistant cuticle, and (c) is a well structured phytoclast with pyrite.

d,e - Poorly preserved phytoclasts. These macerals still exhibit a high degree of structure. However, the cellular contents are beginning to become amorphous. The cell walls show some evidence of fungal attack.

PLATE I

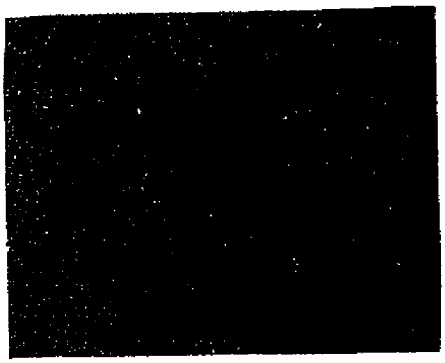


a —— 50 μ

b —— 20 μ

c —— 50 μ

d —— 50 μ



e —— 20 μ

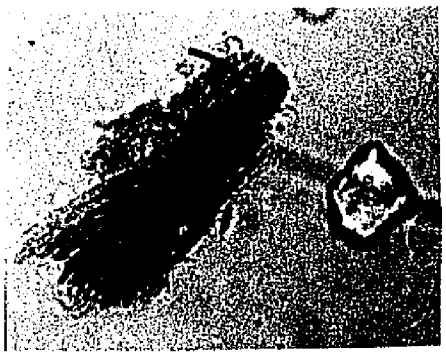
Plate II. Infested, amorphous structured, and amorphous unstructured phytoclasts.

a - Infested phytoclast. Maceral is profoundly attacked by fungal hyphae. The attack is principally within the cell walls where the fungi utilize the cellulose of the lignin-cellulose walls.

b,c - Amorphous structured phytoclasts. These macerals do not exhibit fungal or bacterial attack. The cell walls are still intact, but the cellular contents have gone to an amorphous or gelified state.

c,d - Amorphous unstructured phytoclasts. These macerals also do not exhibit fungal or bacterial attack. The cell walls are not present and the cellular contents have gone to an amorphous state. The maceral often has a vitreous appearance as in (d).

PLATE II



a —— 10 μ

b —— 20 μ

c —— 10 μ

d —— 20 μ

e —— 20 μ

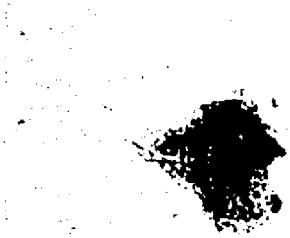
Plate III. Amorphous infested phytoclasts and amorphous infested indeterminate.

a,b - Amorphous infested phytoclasts. This maceral group exhibits the structural, angular outline of the phytoclasts. The cellular contents are extremely bacterially biodegraded and in some cases may be fungally degraded as in (a).

c,d - Amorphous infested indeterminate. This maceral group is a category for all highly degraded organic particles that cannot be positively classified into any existing type. The maceral may form from precipitated organic substances as in (c), or as highly degraded primary plant particles as in (d).

PLATE III

a —— 10 μ



b —— 10 μ

c —— 10 μ

d —— 10 μ

Plate IV. Amorphous protistoclast, fungal hyphae, inertinite, and miospores.

a - Amorphous protistoclast. The fluffy and cloudlike appearance is diagnostic of the degradation of algal material. The particles are a combination of algal cells and bacterial bodies.

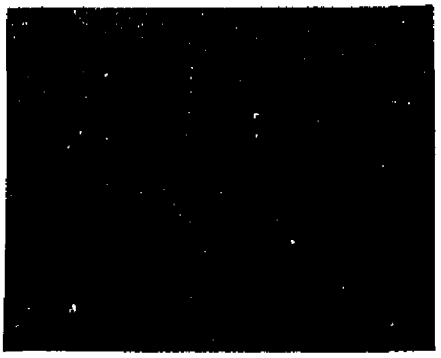
b,c - Scleratoclasts. The scleratoclasts are isolated particles of fungi or bacteria. (b) and (c) are examples of the most common scleratoclast encountered in this study, i.e., fungal hyphae.

d - Inertinite. These macerals are the carbonized products of higher plants. They are opaque under transmitted light and highly angular in outline.

e - Miospore. Pollen and spores are classified as miospores. (e) is an example of a monoporate, broken angiosperm pollen grain.

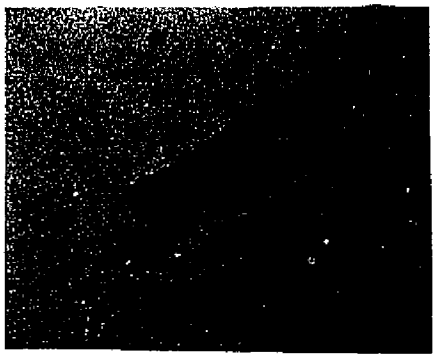
PLATE IV

a —— 20 μ

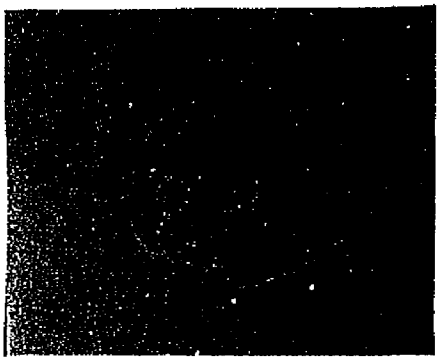


b —— 20 μ

c —— 10 μ



d —— 50 μ



e —— 10 μ

non-marsh sediments clustered into three groups. Two lake clusters (designated lake I and lake II), and a splay. Figures 27 and 28 illustrate the mean maceral assemblage for each environmental cluster.

A distance coefficient matrix portrayed the degree of similarity between each cluster group (Table IV). Higher numbers indicated greater similarity among the environmental groups. From the distance coefficient matrix, a dendogram was constructed (Figure 29) according to the weighted pair group method (Sokal and Sneath, 1963). The dendogram illustrates the hierarchial degree of similarity among maceral assemblage clusters.

Examination of the dendogram revealed the splay deposits to be very different from the other six environments. This environment was characterized by high relative abundances of amorphous structured phytoclasts and inertinite, with lower abundances of scleratoclasts and amorphous protistoclasts (Figure 28c). Of the remaining six environments, the saline marsh was unique. The maceral assemblage for the saline marsh was characterized by high abundances of poorly structured phytoclasts, infested phytoclasts, and amorphous infested indeterminate macerals (Figure 27a). The two lake clusters were closely related. The lake environments contained relatively high abundances of scleratoclasts and amorphous protistoclasts. The

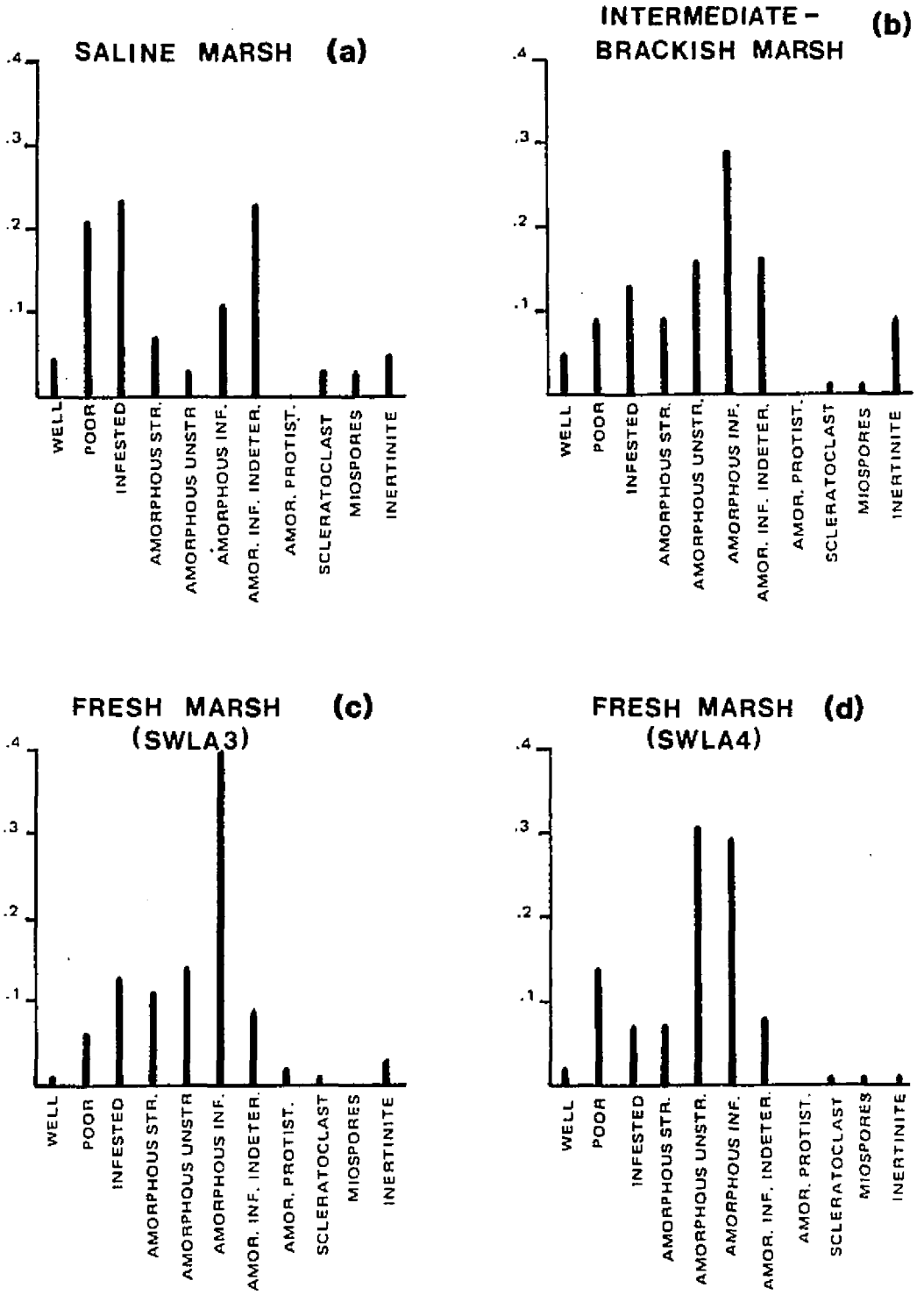


FIGURE 27. Maceral Assemblages of the Marsh Environments (Mean of Cluster).

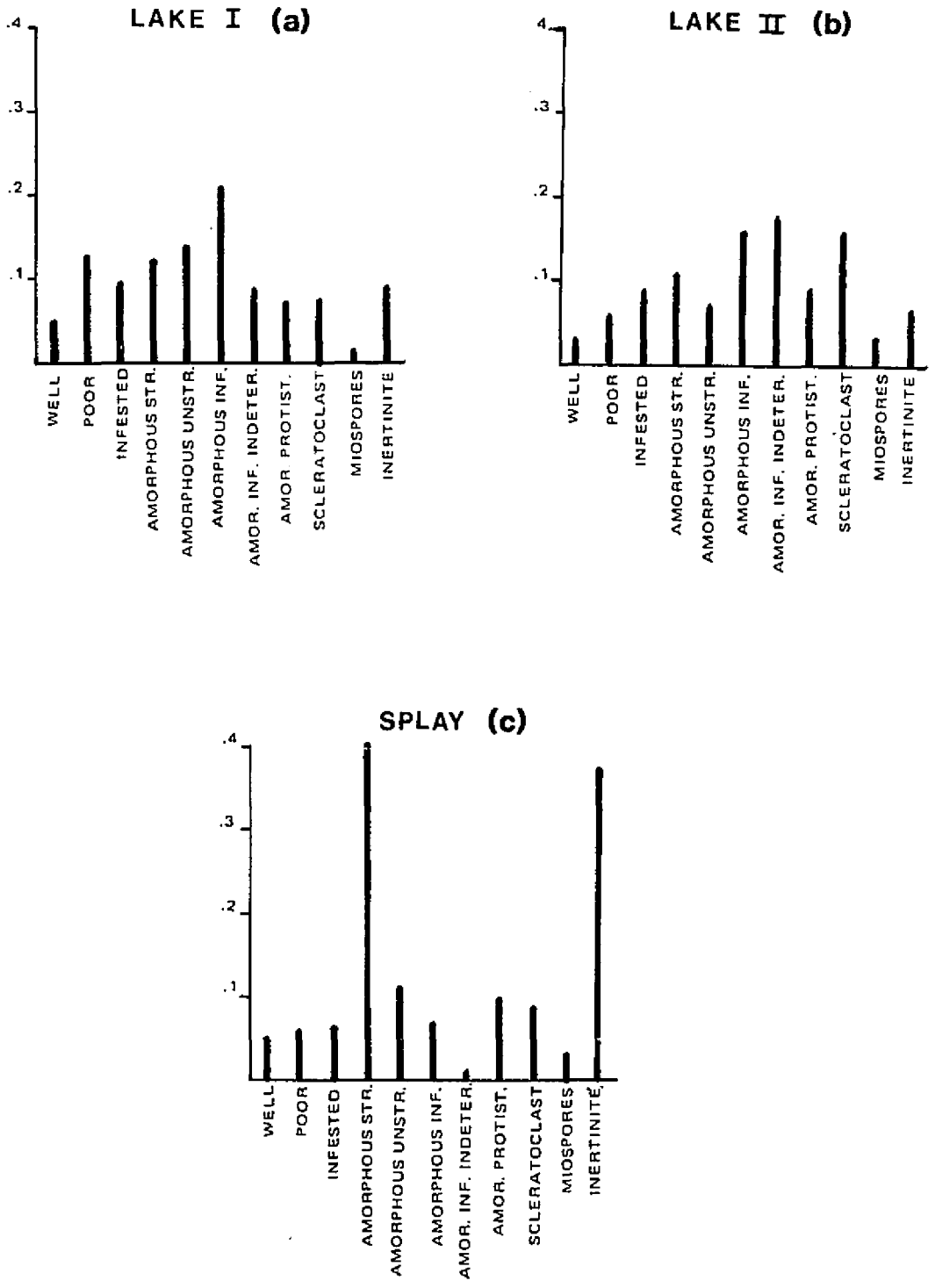


FIGURE 28. Maceral Assemblages of the Non Marsh Environments (Mean of Cluster).

TABLE IV. MACERAL DISTANCE COEFFICIENT MATRIX

	SALINE MARSH	LAKE I	LAKE II	FRESH MARSH SWLA3	INTER.-BR. MARSH	FRESH MARSH SWLA4	SPLAY
SALINE MARSH	X						
LAKE I	8.98	X					
LAKE II	8.83	9.31	X				
FRESH MARSH SWLA3	8.32	8.74	9.19	X			
INTER-BR. MARSH	8.98	9.12	9.34	9.52	X		
FRESH MARSH SWLA4	8.14	8.48	9.04	9.28	9.34	X	
SPLAY	6.44	4.94	7.72	6.34	4.08	6.16	X

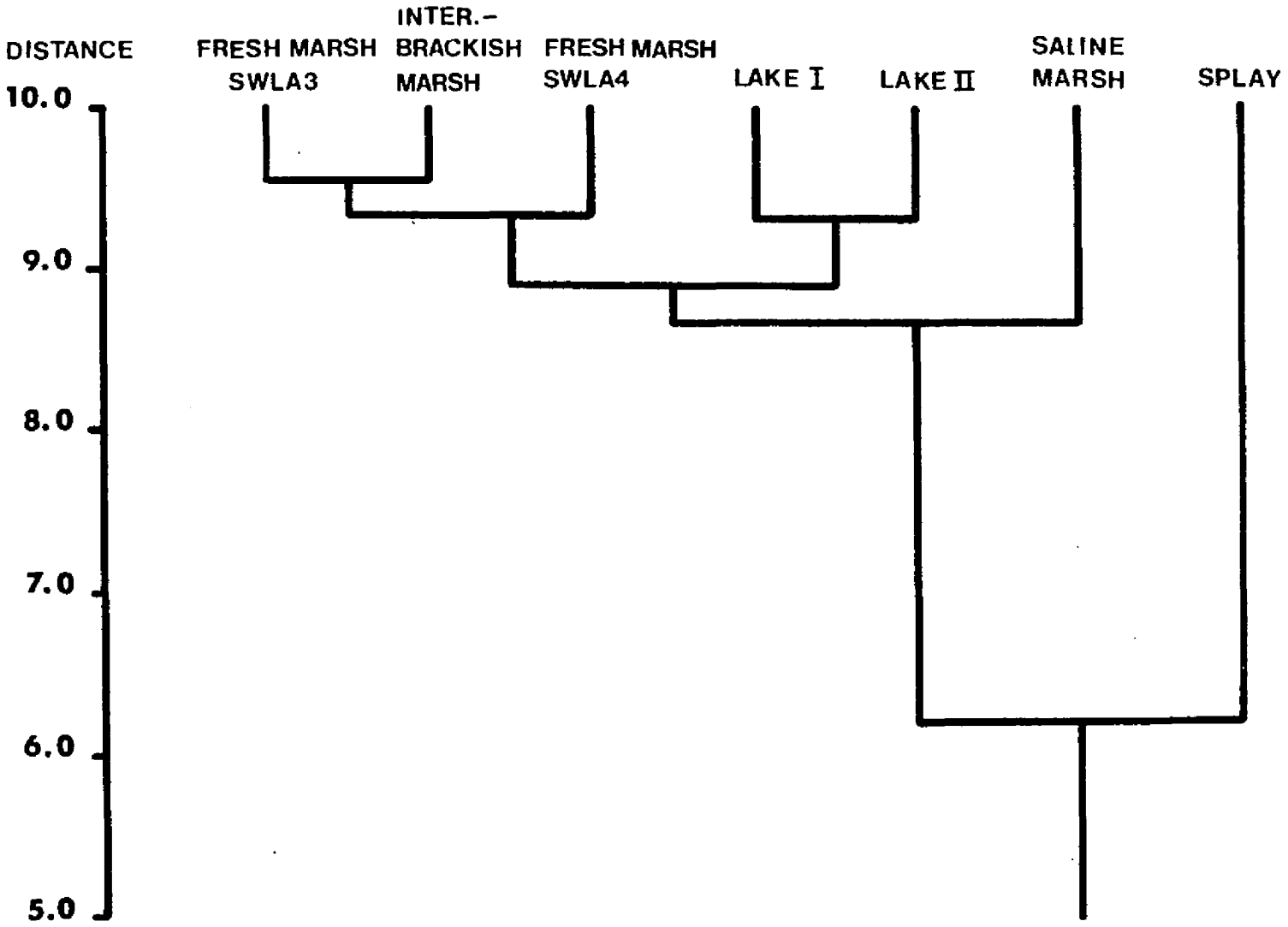


FIGURE 29. Maceral Dendogram.

remaining three environments (fresh marsh SWLA4, fresh marsh SWLA3, and intermediate-brackish marsh) were closely related and characterized by high abundances of amorphous infested macerals. These three environments were also noticeably devoid of scleratoclasts (Figures 27 b,c, and d).

Processes of organic sedimentation and degradation

The maceral assemblages were used to determine processes of organic matter sedimentation and degradation in the paleoenvironments from the three study cores. Since the maceral classification scheme is based on a degradation index, the results of the maceral analysis were used to ascertain chemical, physical, and biological processes of organic matter preservation.

Marsh Series

All marsh environments contained predominantly higher plant (phytoclast) derived organic matter. The saline marsh samples contained the highest relative abundances of the amorphous infested indeterminate (A.I.I.) macerals. Furthermore, there was a steady decrease in the relative abundances of the A.I.I. macerals in the following order: saline marsh › intermediate-brackish marshes › fresh marshes. The A.I.I. maceral is a highly amorphous globular

mass of organic matter. Formation of these macerals in the marsh sediments could have occurred by flocculation of humic acids. This process is known to occur during mixing of fresh and saline waters, as humate material is precipitated out of solution as flocculates (McFarlane, 1978). Furthermore, Sholkovitz (1976) reported an increase in the precipitation of humic acids as the salinity of the mixed water increased. Sholkovitz also noted that maximum flocculation occurred between salinities of 15 to 20 ppt. The salinity range of maximum flocculation coincides with reported mean salinities of saline marshes in Louisiana (Chabreck, 1972). Therefore, decreases in the relative abundances of the A.I.I. macerals from saline to fresher marshes was a function of the decreasing salinity gradient. Precipitation of humic acids in saline marsh samples represented an important mechanism of organic matter sedimentation. Swanson et al. (1972) reported that approximately 20% of the total organic matter in tidal marsh sediments from the northeast Gulf of Mexico was derived by floculation of humic acids.

The saline marsh peats also contained high abundances of fungally derived macerals (poorly structured phytoclasts, infested phytoclasts, and scleratoclasts). Since these macerals are the product of aerobic fungal degradation, oxidative conditions occurred during some depositional or early diagenetic phase of sedimentation.

The oxidative process may be a result of the low water levels in the saline marsh, allowing oxygen to diffuse to the surface of the marsh.

The intermediate, brackish, and fresh marsh peats did not contain significant abundances of fungally derived macerals. Major maceral types in these peats were the amorphous, and amorphous infested phytoclasts. Therefore, a bacterial and chemical degradation pathway was the predominant controlling agent affecting the type of organic matter accumulating in these environments.

In summary, peats from the marsh facies contained organic matter of higher plant origin in the form of primary plant structures and precipitated humate particles. The saline marsh was more oxidized and contained greater abundances of precipitated humate matter. Fresher marshes were more anoxic, characterized by lower abundances of fungal material, and higher abundances of bacterially degraded higher plant remains.

Non-Marsh Series

The non-marsh sediments consisted of the two lake environments and the splay deposit. Depositional environments were derived from sedimentology and fossil analyses. As compared to the marsh facies, all three environments were relatively more oxidized (high scleratoclast content) and

contained a significant algal component (amorphous protistoclasts).

The lake facies in this study received their organic matter from adjacent fresh, intermediate, or brackish marshes (as seen by the close similarity among the environmental clusters). The scleratoclast content of the lake environments was also higher than the adjacent marshes, implying oxidizing sedimentary conditions. Amorphous protistoclasts were common in the lake samples, indicating a substantial algal community.

The maceral assemblage of the splay deposits indicates an allocthonous input of reworked and recycled organic particles. This environment contained high abundances of amorphous structured macerals and inertinite. These macerals survived oxidative processes during transportation and were thus deposited by hydrodynamic processes into the splay environment. There is strong evidence that some of the particulate organic fraction in the splay deposits was derived from ancient sediments. The color indices of the well structured phytoclasts (cuticles) and miospores were significantly higher in the splays as compared to the other environments, indicating some input from recycled thermally altered ancient sediments.

The mechanisms of organic matter sedimentation discussed in this section are depicted as a generalized illustration in Figure 30. The illustration is not intended to describe all of the complicated factors that constitute organic matter sedimentation and preservation in deltaic environments. It rather represents an attempt to summarize the results and conclusions derived from the maceral analysis.

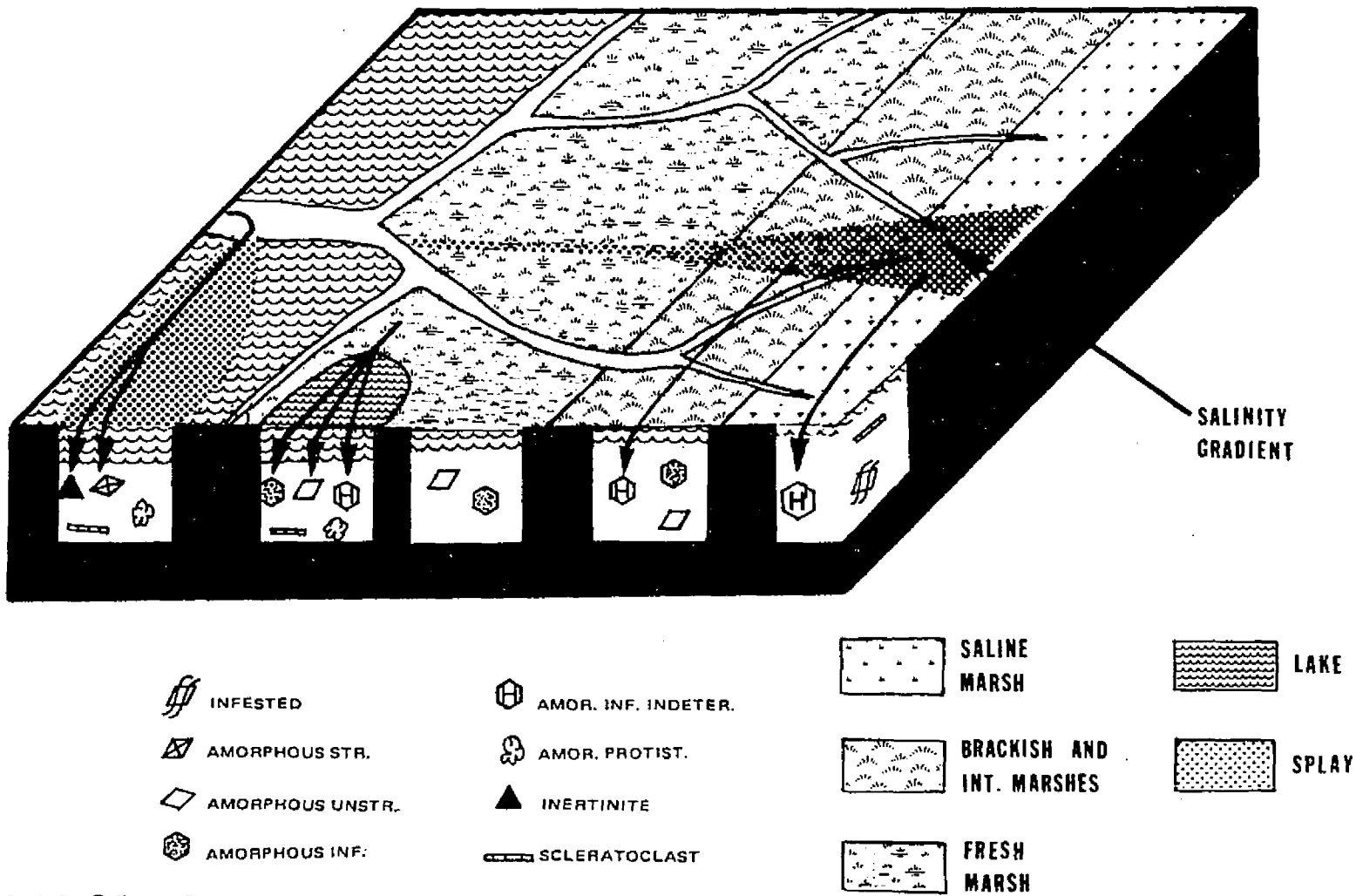


FIGURE 30. Some Origins of Macerals in Peats and Associated Sediments

IX. TOTAL ORGANIC CARBON (T.O.C.)

The total organic carbon content of a sediment is a quantitative measure of the amount of organic matter preserved in a sedimentary rock. This quality parameter is a complex product of many depositional and diagenetic factors. The organic content of a rock is dependent on autocthonous organic production, allocthonous organic input, sedimentation rate, reworking losses, redox potential, climate, type of organic matter, biodegradation, and diagenesis.

Peats are deposited, for the most part, within an autocthonous setting of high terrestrial input. The important factors affecting the organic carbon content within peat-forming environments are primary productivity, exportation losses, sedimentation rate, biodegradation, and redox potential.

Within the peat forming environments of the Louisiana coastal region, there is a general trend of decreasing organic matter content with increasing marsh salinity (Figure 31).

The T.O.C. content of the sediments in this study was used as an organic matter quality parameter in conjunction

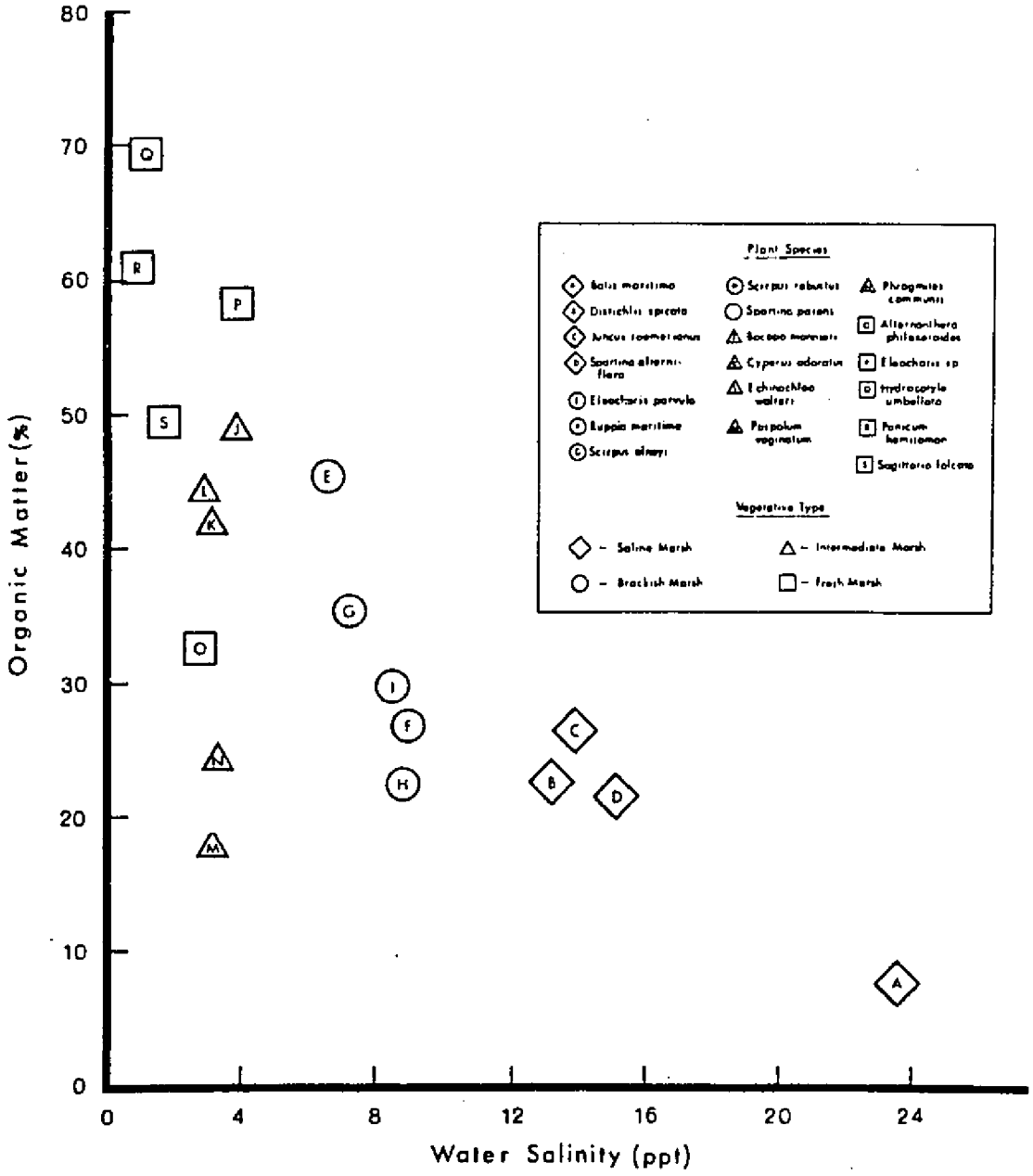


FIGURE 31. Distribution of Major Marsh Plants in Relation to Water Salinity and Organic Matter. (Palmisano and Chabreck 1972)

with the maceral composition, floral assemblage, and salinity history.

Methods

The sediments were dried in an oven (50-60^{0}C) and finely ground. Carbonates were removed by overnight digestion in 6N HCl. The HCl was washed out of the samples by filtration and the sample redried in the oven (50-60^{0}C). Duplicate analyses of all samples were determined on a Leco carbon analyzer. The total organic carbon is reported on a % dry weight basis.

Results

The total organic carbon depth profiles of the sediments recovered from the three study cores are depicted in Figure 32. A wide range of organic carbon contents was encountered in the sediments, ranging from 0.30% in the silty-sands, to 46% in the organic rich peats.

Within the marsh peats, considerable variation in the organic carbon content existed. The saline marsh peats generally exhibited the lowest organic carbon content, while the fresher peats had higher organic carbon contents.

By itself, the T.O.C. content has limited value as an indicator of peat-forming environments. However, in

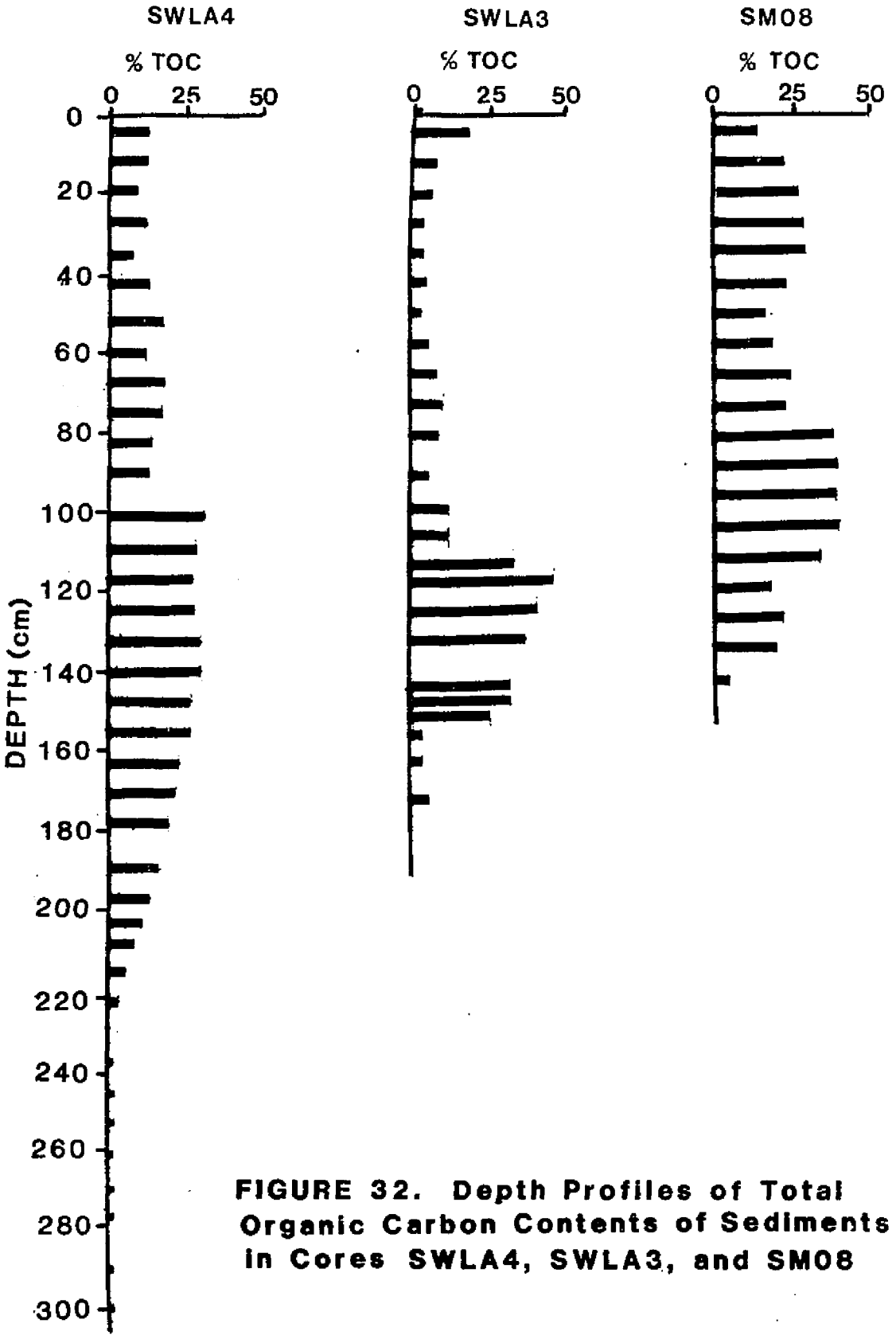


FIGURE 32. Depth Profiles of Total Organic Carbon Contents of Sediments in Cores SWLA4, SWLA3, and SM08

conjunction with other parameters, such as the maceral content, T.O.C. content is a powerful organic matter quality parameter. In the discussion section, the results of the total organic carbon analyses will be integrated with other indices to describe the quality of the sediment.

X. PALEOSALINITY ANALYSIS - CHEMICAL METHODS

The salinity of the overlying water is the single most important factor controlling the type and quality of a peat deposit in the coastal Louisiana marshlands (Penfound and Hathaway, 1938). Furthermore, the paleosalinity history of a deltaic core sequence provides a record of the deltas progradation and abandonment.

It was demonstrated in the previous sections that fossil analyses (foraminifera and gemmules) can accurately resolve slight changes in paleosalinity from cored sediments. However, these methods are time consuming and labor intensive. Therefore, alternate chemical and mineralogical paleosalinity methods were investigated.

The paleosalinity determinations from the fossil analyses provided a unique opportunity to assess the utility of the proposed chemical methods. The chemical methods investigated in this section are: (1) the ratio of exchangeable Mg to exchangeable Ca (Mg^{++}/Ca^{++}), (2) the organic carbon to organic sulfur ratio ($T.O.C./S_{organic}$), and (3) mineralogy by X-ray diffraction.

Exchangeable Mg^{++} and Ca^{++}

Cation exchange occurs on clay particles when fluvially derived clastic material is deposited in a marine environment (Spears, 1973; Russell, 1970; Drever, 1971). These studies demonstrated overall decreases in the cation exchange capacity (CEC) of clays in the marine environment. Furthermore, a relative increase in exchangeable Mg^{++} was observed in the clay fractions of marine sediments.

Spears (1973) studied the exchangeable cations of sediments recovered from an ancient freshwater coal sequence interrupted by a major marine event. The paleosalinity of the sediments was determined by fossil methods. He observed higher exchangeable Mg^{++}/Ca^{++} in the marine-influenced sediments relative to the freshwater sediments. The exchangeable Mg^{++}/Ca^{++} of the fresh sequence averaged 0.35, while the marine-influenced sediments averaged 1.70.

Mobbs (pers. comm.) measured exchangeable Mg^{++}, Ca^{++}, and salinity on sediments from the Atchafalya delta, Louisiana. His data also revealed an increasing exchangeable Mg^{++}/Ca^{++} with increasing salinity.

Figure 33 is a plot of salinity vs. exchangeable Mg^{++}/Ca^{++} derived from the data in the previously mentioned

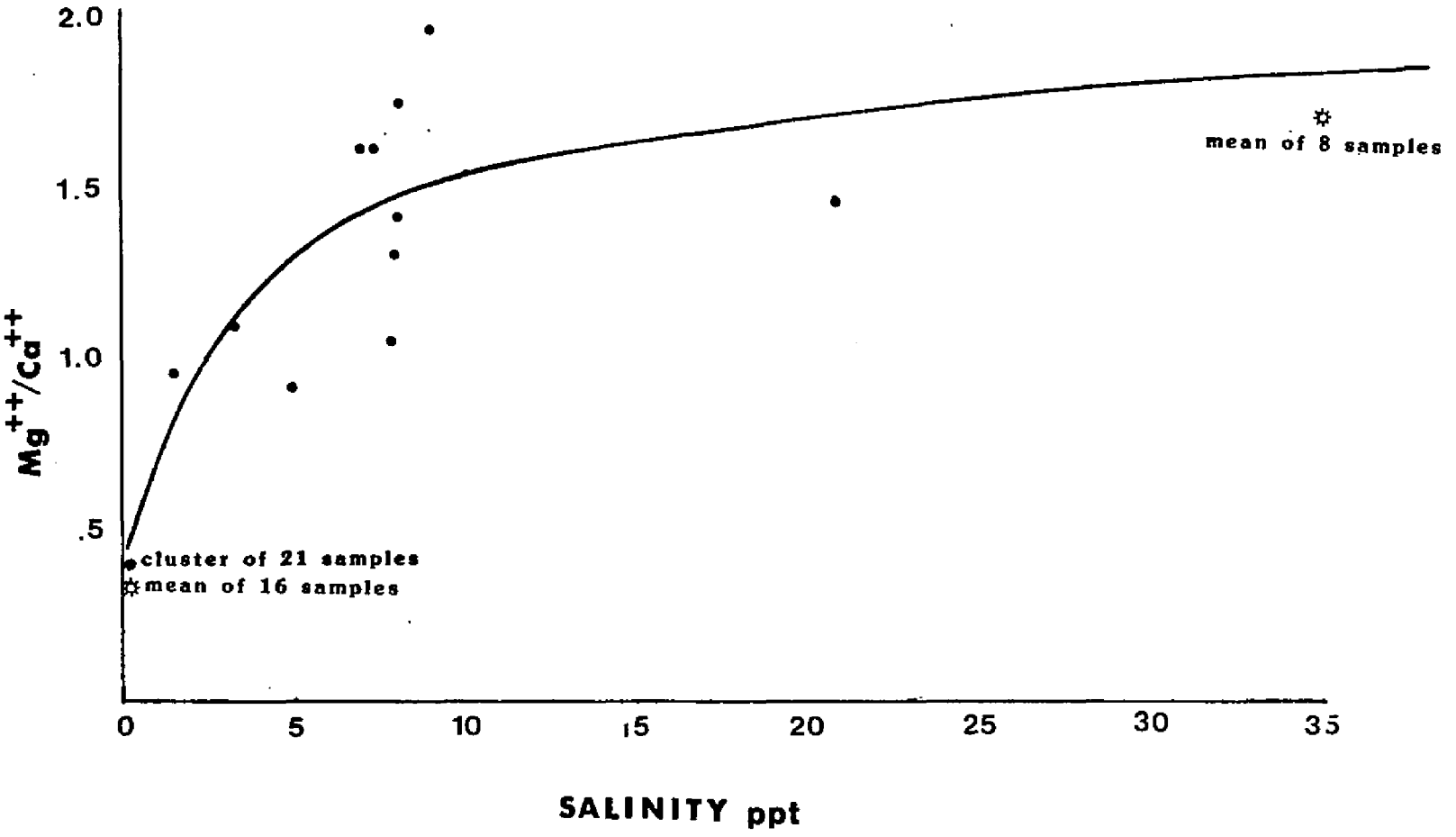


FIGURE 33. Exchangeable Mg/Ca vs. Salinity from Previous Studies.

studies. Several regression models were tested with the best fit determined as logarithmic (r^2=.88).

The relationship between exchangeable Mg^{++}/Ca^{++} and salinity was tested on core SWLA3.

Methods

Exchangeable Mg^{++} and Ca^{++} were measured according to procedures described by Spears (1973). Approximately 250 mgs of dried and ground samples were placed in beakers and washed three times with distilled water to remove water soluble cations. Exchangeable cations were isolated by extracting the samples with 20 ml of a 1 molar ammonium acetate solution buffered at pH 7.0. The samples were centrifuged, decanted, and diluted. The Mg^{++} and Ca^{++} were measured on a Perkin Elmer atomic absorption spectrophotometer.

Results

Seven samples from core SWLA3 were analyzed for exchangeable Mg^{++} and Ca^{++}. Core SWLA3 was chosen for this exercise since it contained the greatest range of salinity influenced sediments. Mesohaline conditions existed in the surficial saline marsh samples, oligohaline conditions existed in the basal intermediate to fresh marsh sediments, while near marine conditions occurred in the lake deposits from the middle of the core.

Exchangeable Mg^{++}/Ca^{++} was calculated for each sample and plotted as a depth profile (Figure 34). The depth profile reveals almost constant values of 1.5 throughout the core. Considering the true paleosalinity profile of the core, the only predicted values of the ratio existed in the surficial saline marsh samples. Exchangeable Mg^{++}/Ca^{++} of the fresh and intermediate marsh samples was higher than expected, while the exchangeable Mg^{++}/Ca^{++} of the lake samples was lower than expected. Therefore, exchangeable Mg^{++}/Ca^{++} did not accurately portray the true paleosalinity (fossl methods) at time of deposition of most samples in core SWLA3. No further attempt was made to apply this method to cores SWLA4 and SM08.

The lack of correlation between exchangeable Mg^{++}/Ca^{++} and paleosalinity in the sediments analyzed in this study may be indicative of the highly dynamic nature of interdistributary basin formation. Vertical communication of pore waters in the core, in conjunction with increasing and fluctuating salinity, may have allowed vertical migration of water soluble cations. Re-equilibration at depth could have caused a change in the exchangeable Mg^{++}/Ca^{++}.

The lower than expected exchangeable Mg^{++}/Ca^{++} values in the lake sediments and higher than expected values in the fresh sediments may also be a result of selective downward diffusion of Mg^{++}. Drever (1971) observed high

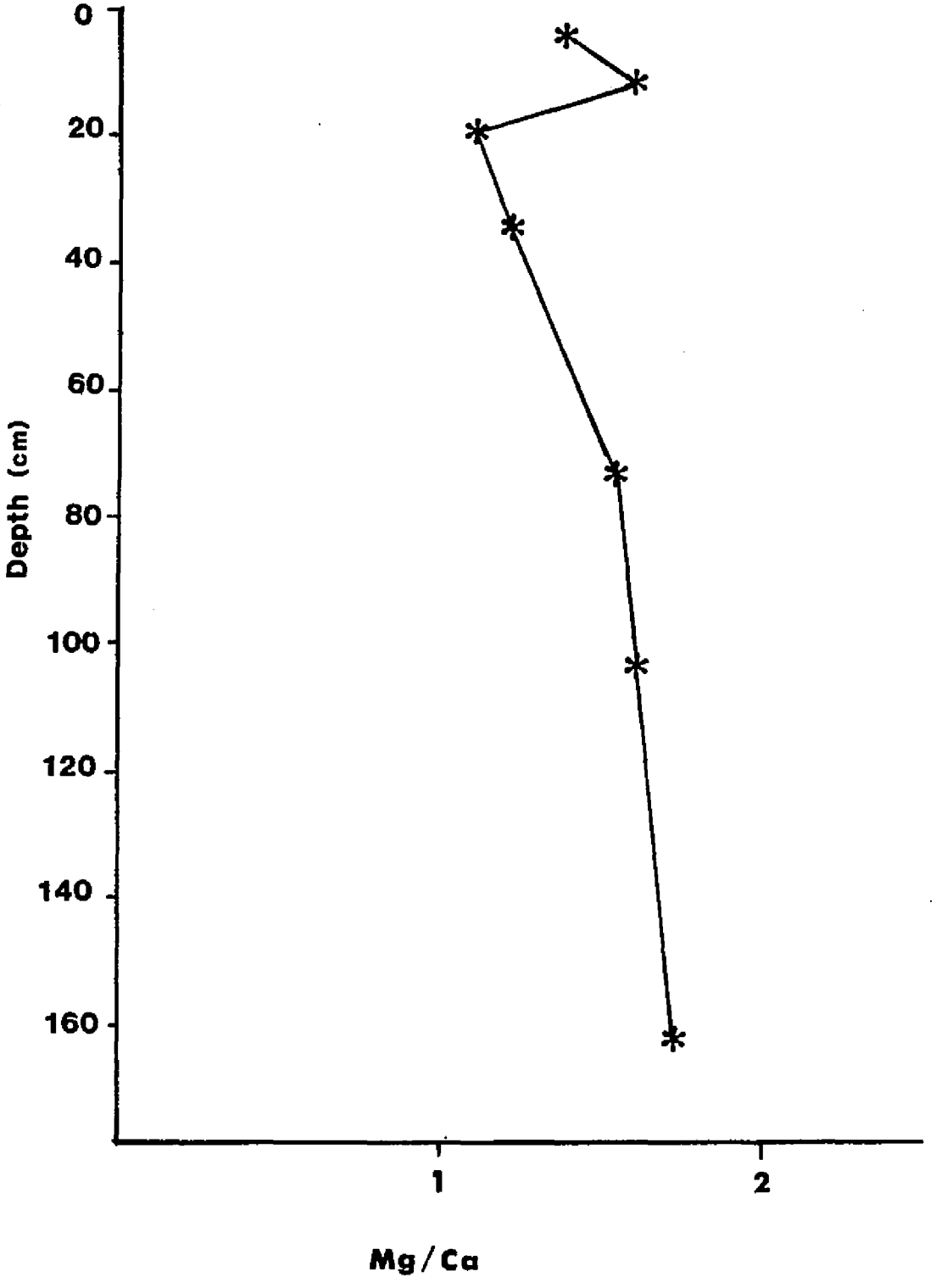


FIGURE 34. Exchangeable Mg/Ca vs. Depth in Core SWLA3.

uptakes of Mg^{++} in anaerobic sediments. He also noted a downward diffusion of Mg^{++} from oxidized sediments to more reduced sediments. A similar process may have been operative in core SWLA3. The Mg^{++} from the relatively aerobic lake sediments may have migrated to the underlying anaerobic Mg^{++} depleted fresh marsh peats. This mechanism would account for the lower than expected exchangeable Mg^{++}/Ca^{++} values in the lake sediments, and the higher than expected values in the fresh marsh peats.

In conclusion, the exchangeable Mg^{++}/Ca^{++} was not an acceptable paleosalinity method for sediments in the study cores.

Mineralogy by X-ray Diffraction

The mineralogy of eight samples from core SWLA3 was undertaken to detect mineralogical differences due to changing sources of sediments or salinity. The possibility of recognizing the change in sediment source due to the regional salinity intrusion was investigated. In addition, the effect of salinity on mineralogic content was also examined. Core SWLA3 was chosen for this exercise since it contained the most diverse sediments and greatest changes in salinity.

Methods

Eight samples from the major environmental types of core SWLA3 were prepared for X-ray diffraction analysis. The organic matter in the samples was removed by repetitive digestions in a 1:4 mixture of hydrogen peroxide (40%) and sodium hypochlorite (Chlorox). The organic free sediments were then repeatedly washed, centrifuged, and decanted to remove any soluble digestion products.

A bulk powder analysis from 4 to 65° 2θ was undertaken to determine the major clastic constituents. Oriented specimens of the clay sized fraction were made by drop pipeting a slurry of clay and water on a glass slide. These oriented specimens were analyzed between 2 to 17° 2θ in both an untreated and glycolated state.

All digestions and diffractograms were analyzed in duplicate.

Results

No significant differences existed among the samples in their bulk mineralogy. The bulk powder diffractograms revealed major quartz, along with minor feldspar, carbonates, kaolinite, illite, and poorly resolved mixed layer clays.

X-ray diffraction of the clay-sized fraction revealed significant between sample variations. However, none of the differences among the samples could be attributed to source or salinity effects. Figures 35 to 38 are plots of the glycolated X-ray diffractograms at each sample depth interval. The major clay constituents were mixed layer clays, mica, and kaolinite.

Significant differences between samples were found in the mixed layer clay peaks. Initial observations revealed the highly carbonaceous sediments to contain broad and poorly resolvable mixed layer clay peaks. The less organic sediments exhibited more sharply defined peaks. The broad and poorly defined peaks represented poorly crystallized mixed layer clays. A quantitative measure of mixed layer clay crystallinity was derived from a ratio of the peak width to height. A large width to height ratio indicated poorly crystallized mixed layer clays.

The width to height ratios of each sample's mixed layer clay peaks were plotted against the total organic carbon content of the sediment (Figure 39). A linear and positive relationship existed between the width to height ratio (crystallinity index) and the T.O.C. content. As the total organic carbon content of the sediments increased, the crystallinity of the mixed layer clays decreased. This relationship yielded a highly significant r^2 of .95.

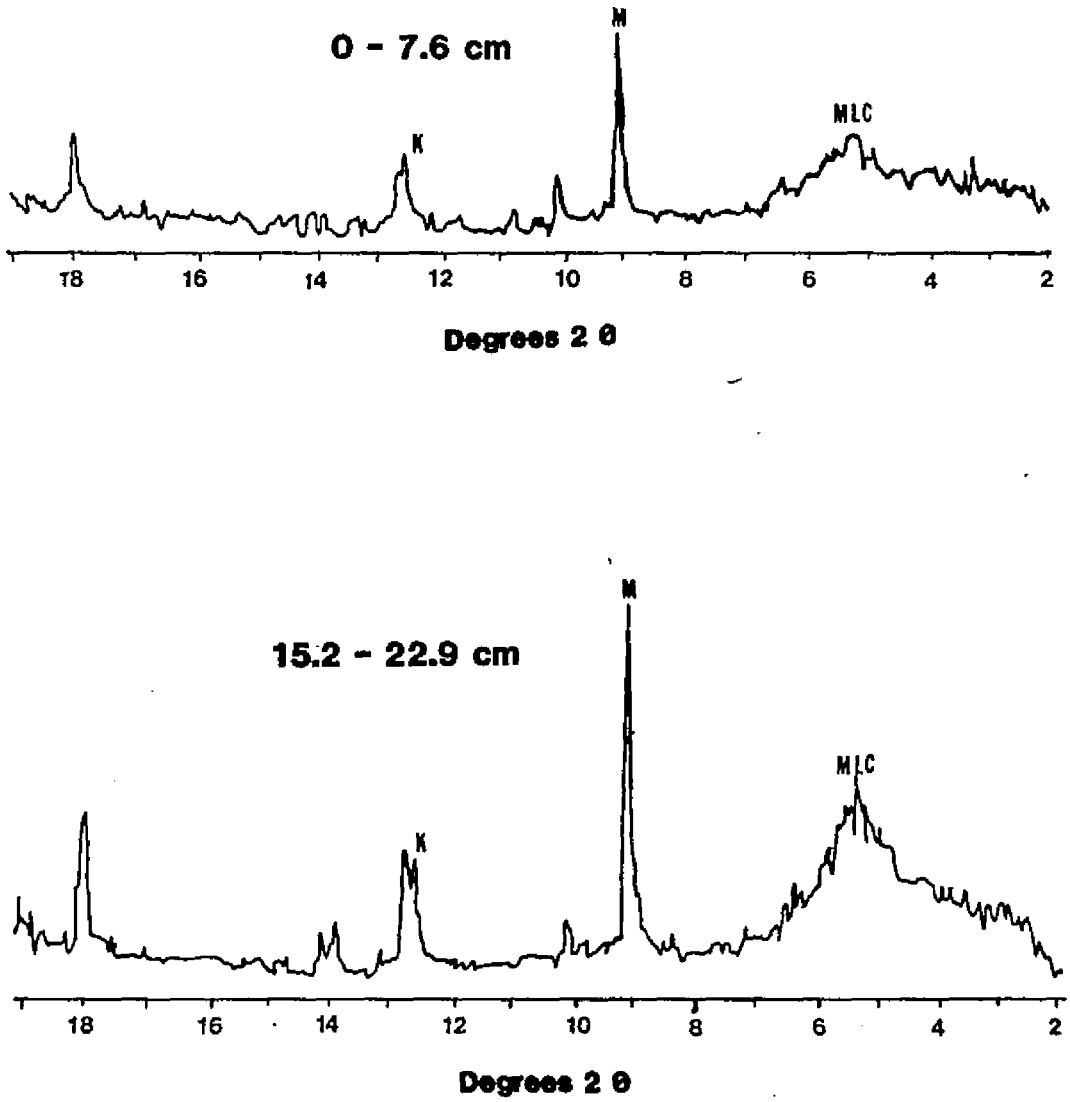


FIGURE 35. Glycolated X-Ray Patterns of the Clay Sized Fraction from Core SWLA3.

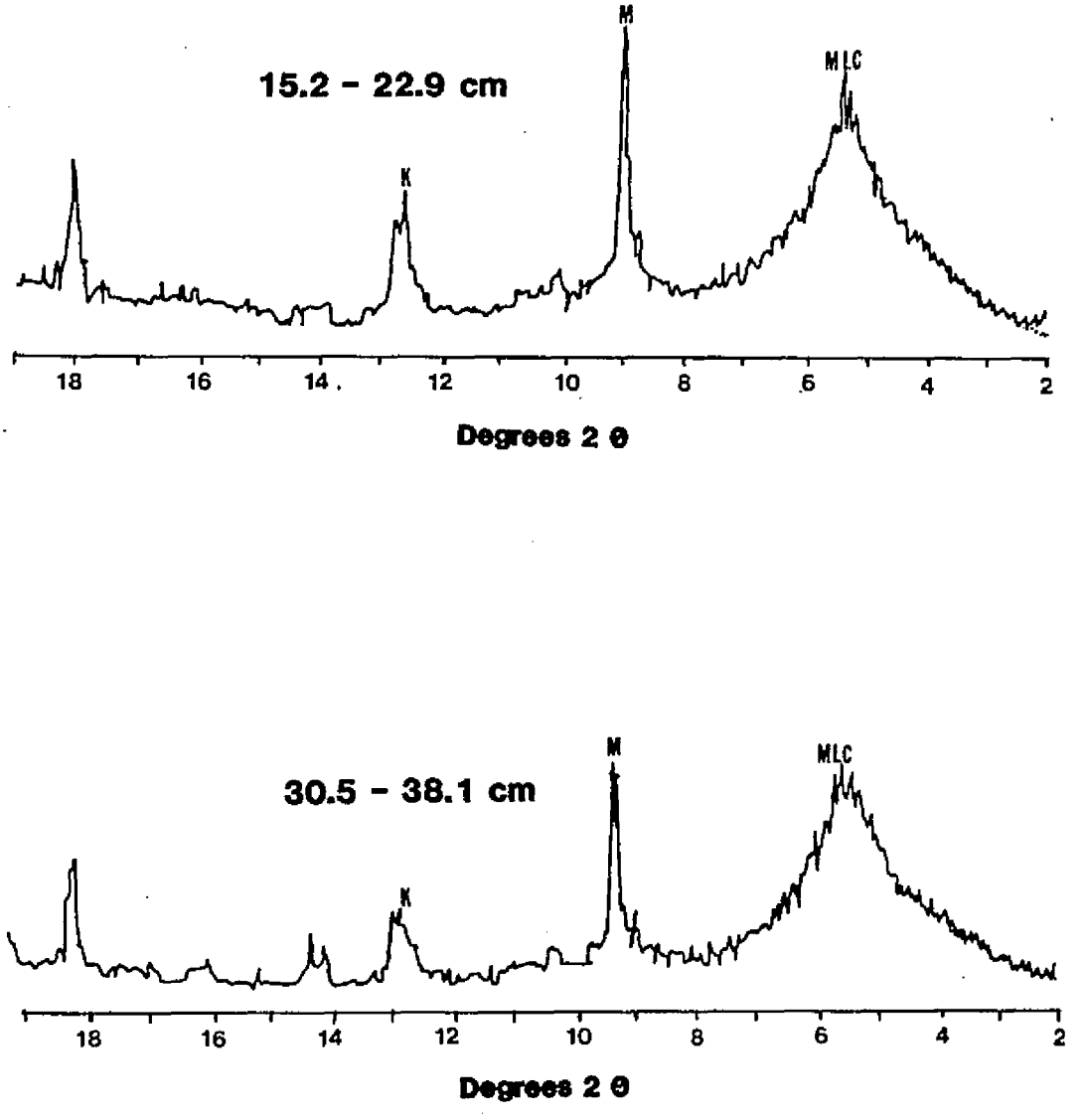


FIGURE 36. Glycolated X-Ray Patterns of the Clay Sized Fraction from Core SWLA3.

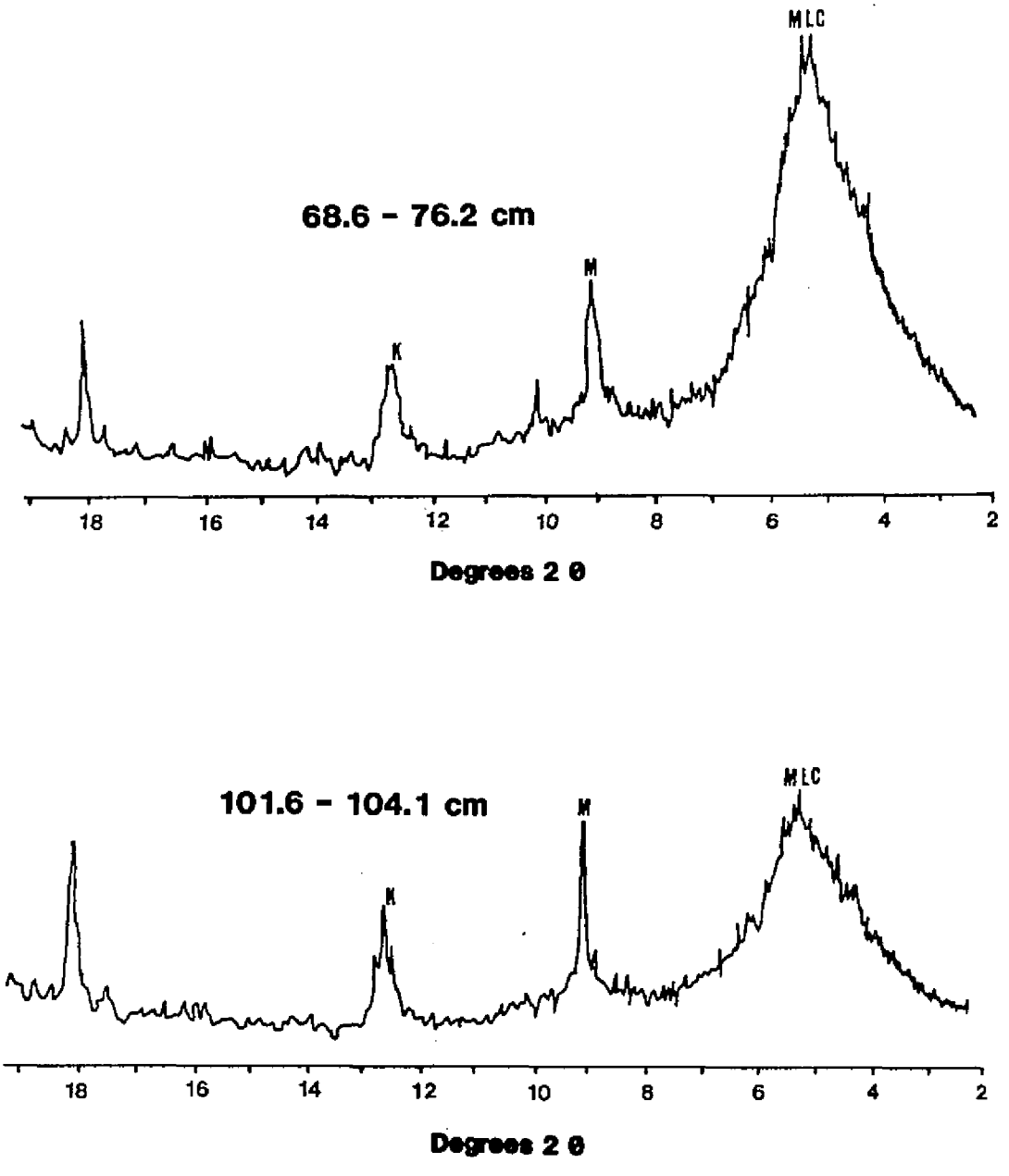


FIGURE 37. Glycolated X-Ray Patterns of the Clay Sized Fraction from Core SWLA3.

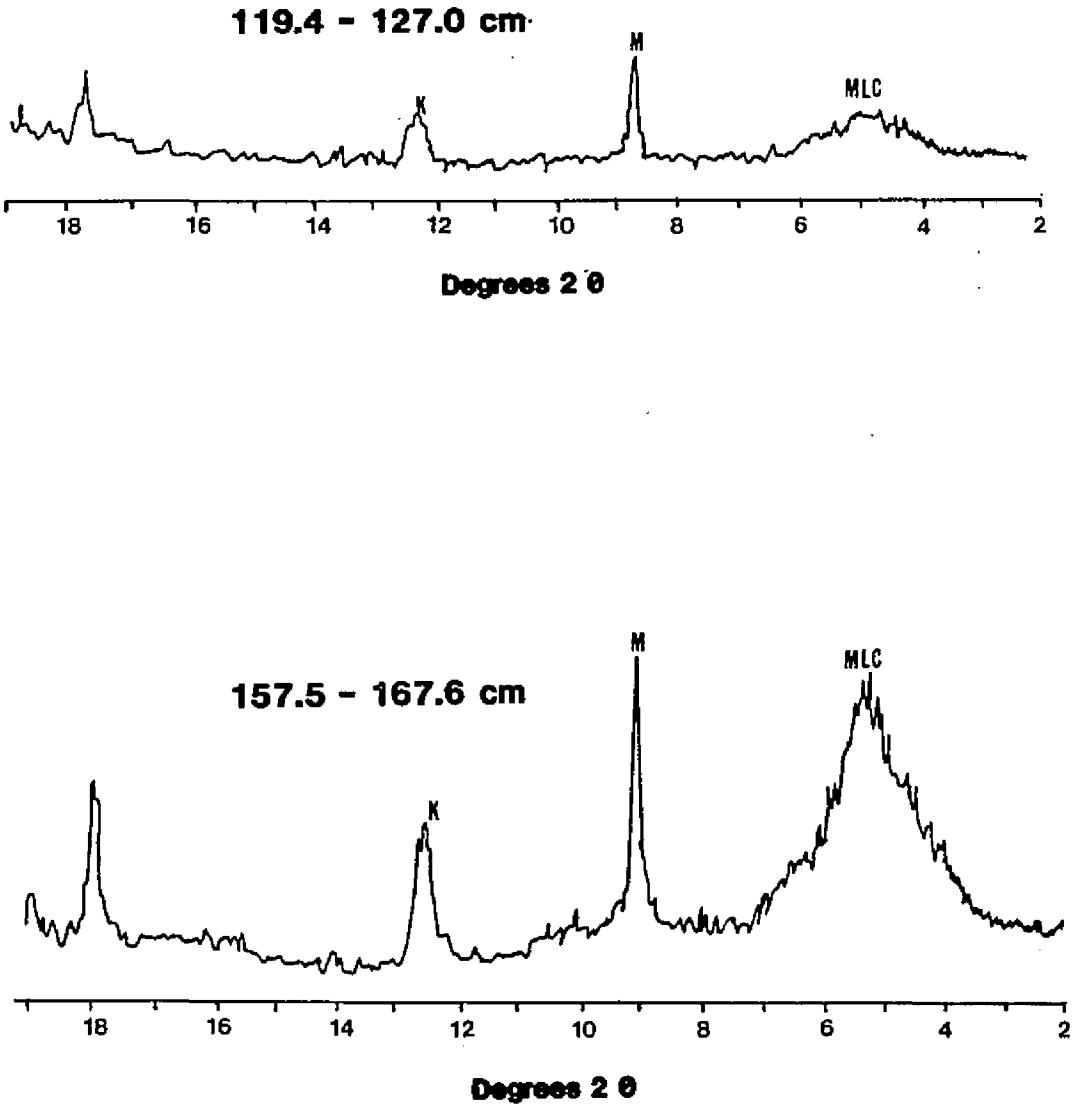


FIGURE 38. Glycolated X-Ray Patterns of the Clay Sized Fraction from Core SWLA3.

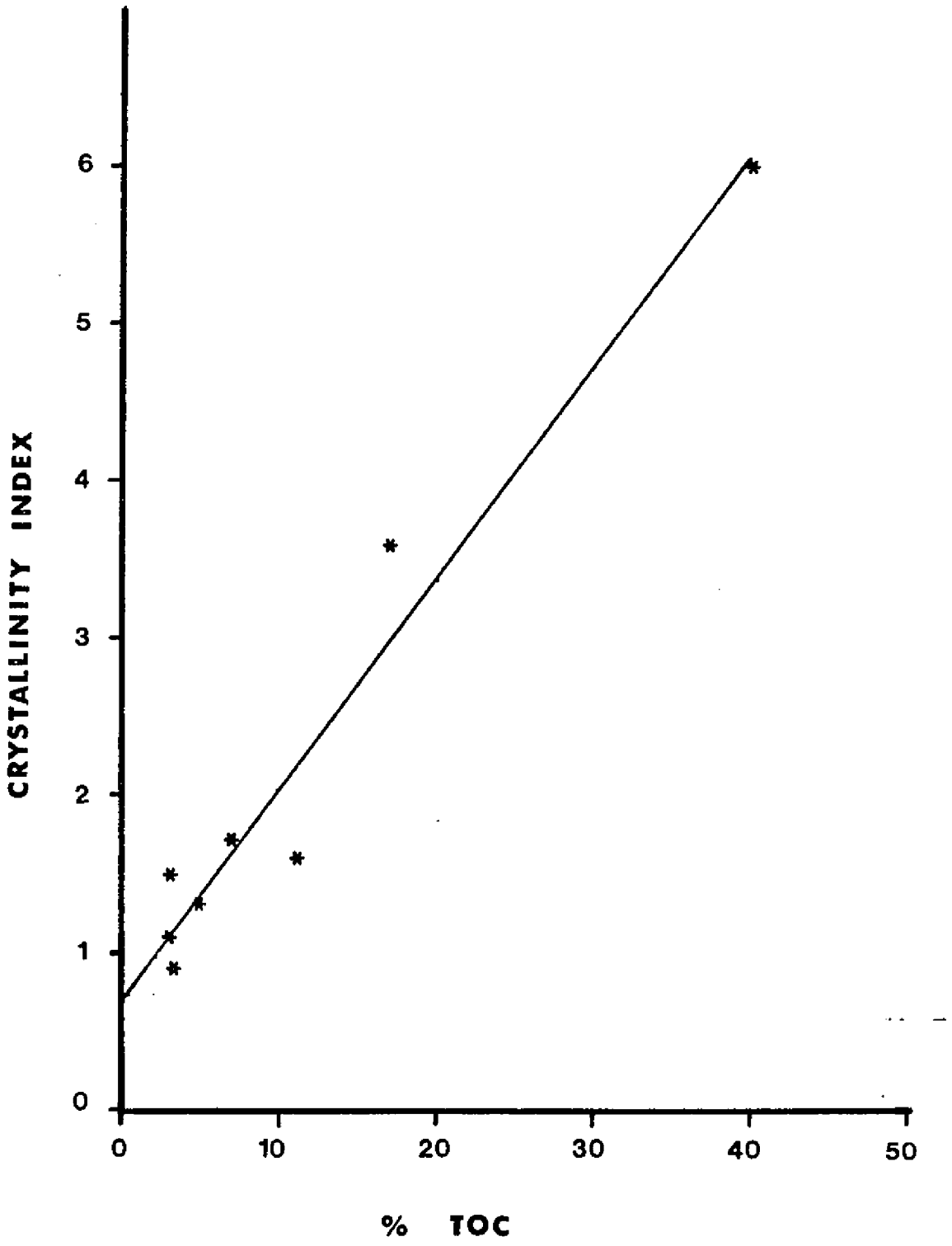


FIGURE 39. Crystallinity Index vs. % TOC in Core SWLA3.

The organic matter content of the peat or sediment therefore influences the crystallinity of the mixed layer clays. This relationship was also reported by Timofeev and Bogoliubova (1975) in a study of the effects of organic matter on the mineral diagenesis of Recent peat deposits. They observed a progressive disordering and decomposition of montmorillinite with increasing organic content. Montmorillinte was completely absent when the ash content of the peats was below 35%. They concluded that organic matter catalyzes and accelerates clay mineral transformations.

In another study, Tan (1975) treated kaolinitic soils with humic acids. The treatments resulted in gradual decomposition of the Si-O-Si linkages of the kaolinite by humic acid attack.

The conclusions of this exercise are: (1) Differences between mineralogies of samples from core SWLA3 were due to variations in the organic matter content of the sediments. (2) There was no indication of mineralogic differences due to salinity or source.

Organic Sulfur in Peats

The formation of a significant portion of the organic sulfur in peats is related to sulfate concentration (Cassagrande and Ng, 1979; Cassagrande et al., 1979).

Assuming sulfate concentration is related to salinity, and this transformation occurs diagenetically early, then a potential paleosalinity indicator exists.

Peats from the Everglades contained between 30 to 50% of the total sulfur in the organic form (Cassagrande et al., 1979). This organic sulfur existed as either carbon-bonded, or carbon-sulfur-oxygen-bonded (ester sulfates). The contribution from plant sources could not entirely account for the total organic sulfur contents.

Reactions involving elemental sulfur and H_2S with organic matter may play an important role in the formation of organic sulfur in peats and coals (Cassagrande et al., 1979; Cassagrande and Ng, 1979; Cassagrande et al., 1980). Pathways to organic sulfur formation are mediated by the microbial reduction of sulfate to H_2S.

Sulfate is a conservative constituent of sea water; thus, saline water contributes higher fluxes of sulfate to marsh sediments than brackish or fresh water. It is therefore proposed that transformations of sulfate to organic sulfur are partially controlled by the salinity of the overlying marsh water.

The ratio of the total organic carbon content to the organic sulfur content ($T.O.C./S_{organic}$) of peats was investigated as a paleosalinity indicator. The total

organic carbon content was used to place the $S_{organic}$ content on an equal carbon basis. High values of the ratio should indicate minimal organic sulfur formation and thus low salinity.

The relationship between T.O.C./$S_{organic}$ and salinity was observed in surface peat deposits from southeast Louisiana (Hart 1979a). In this study, 60 surface peat samples from the saline, brackish, and fresh marshes were analyzed for T.O.C. and organic sulfur. The study supports the hypothesis of higher salinity producing higher concentrations of organic sulfur (in proportion to the organic carbon content). The mean T.O.C./$S_{organic}$ for the saline, brackish, and fresh marshes were 6.87, 10.12, and 21.06, respectively.

The T.O.C./$S_{organic}$ ratio was measured on 13 samples from core SM08 to test the applicability of this proposed paleosalinity indicator for sub-surface peats. Core SM08 was chosen for this exercise since it contained a continuous peat sequence of saline, brackish, and intermediate marshes.

Methods

Organic sulfur was measured by a method described by Ho et al. (1976). One-half gram of dried and ground peat was washed with .1N HCl, re-dried, and placed into a

platinum crucible with 2.5 grams of Na_2CO_3 and .5 grams of $NaNO_3$. The mixture was fused in a muffle furnace at 900° C for 20 minutes. The fusion converted organic sulfur in the sample to sodium sulfate. The fused residue was washed with distilled water and filtered. The filtrate was transferred to a 50 ml beaker and brought up to a volume of 50 ml by addition of distilled water. One ml of the diluted filtrate was placed in a 50 ml flask to which was added 1 ml gum acacia solution, 1 ml 6N HCl, 9 ml H_2O, and .5 grams $BaCl_2:H_2O$. The absorbance of this mixture was measured on a Pye Unicam spectrophotometer at 420 nm. The sulfur content (as organic S) was calculated by comparing the absorbance values to a standard curve.

Results

The total organic carbon (T.O.C.) of each sample was divided by the organic sulfur values to derive $T.O.C./S_{organic}$. The ratios of the 13 samples in core SM08 were plotted against depth (Figure 40).

A ratio of 7.2 from the surface saline marsh of core SM08 is in agreement with values reported from surface saline marshes (Hart, 1979a). However, sub-surface samples exhibited sharp declines to ratios around 4.0 within the top 10 cm, slowly decreasing with depth to a terminal value of 3.3 at 127 cm.

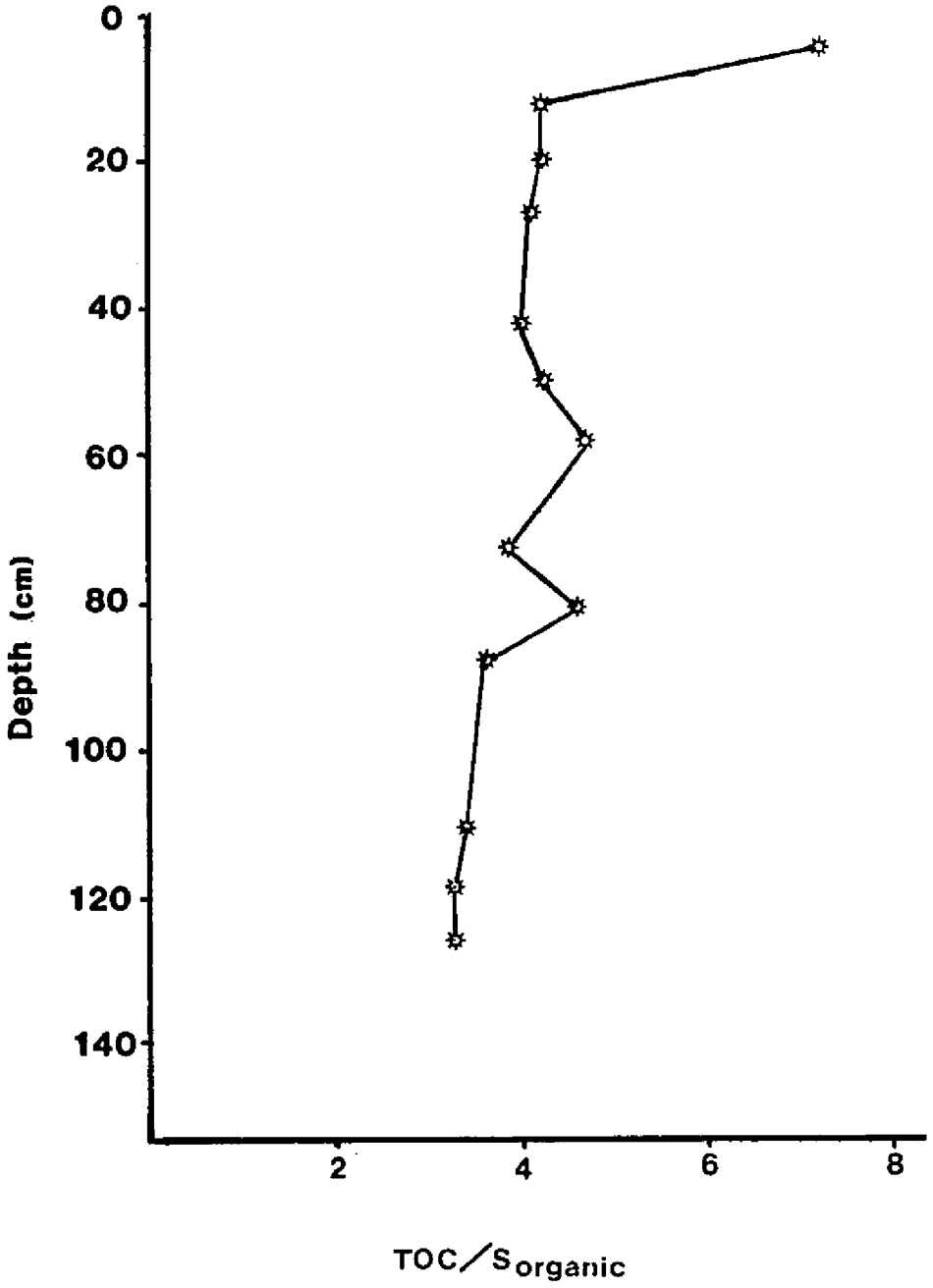


FIGURE 40. TOC/S organic vs. Depth for Core SM08.

The paleoenvironments of core SM08 changed from saline marsh at the surface, to brackish, intermediate, and fresh marshes at depth. The T.O.C./$S_{organic}$ should have increased from the surface value of 7.2 to approximately 20 at 127 cm if the ratios truly portrayed the salinity during deposition. Therefore, the contradictory results from the sub-surface peats indicated that other factors, in addition to salinity at the time of deposition, controlled the formation of organic sulfur. The T.O.C./$S_{organic}$ was an unsuitable measure of marsh paleosalinity for core SM08.

The results of this exercise indicate a downward migration of sulfur. It is also evident that the formation of organic sulfur is not limited to surficial peats.

In a study of salt marsh cores from a Delaware marsh, Lord (1980) observed seasonal, sub-surface oxidizing events. These events led to the destruction of pyrite and the release of significant quantities of sulfate to the pore water system.

If seasonal release of sulfate occurred by pyrite dissolution in core SM08, a steady source of migratable sulfates was available to deeper peat deposits. The migrated sulfur could then have been microbially reduced to H_2S and reacted with the organic matter to form organic sulfur. A constant source of sulfate (sea water) was available to the

surface saline marsh peats to replenish migrated sulfur species.

T.O.C./$S_{organic}$ was not a suitable paleosalinity indicator for buried marsh deposits in core SM08. No further attempt was made to apply this method to the other study cores.

Review of Chemical Salinity Indicators

Results from the chemical and mineralogical paleosalinity studies indicated that these methods were unsuitable for samples in the study area The exchangeable Mg^{++} and Ca^{++}, and T.O.C./$S_{organic}$ studies attempted to relate chemical reactions of surface sediment sea water interactions to stable chemical imprints of salinity. However, the pore water systems of the deltaic sequences were highly active, allowing downward migration of surface fluids. These fluids reacted with the sub-surface sediments, modifying the original chemical imprint.

The mineralogy of the deltaic sediments was found to be more dependent on organic matter and clay interactions than environment of deposition or salinity.

XI. DISCUSSION

The formation and accumulation of peat and associated sediments from the study cores were investigated by integrating the results of the floral study (seeds), paleosalinity reconstructions (foraminifera and gemmules), and organic matter characterizations (T.O.C. and maceral). This approach elucidated the interrelationships among vegetation type, salinity, and the resultant peat quality through time in a changing deltaic setting.

Biostratigraphic correlations among the three study cores, in conjunction with sedimentary data from the augers, were used to investigate interdistributary basin formation within the Lafourche delta.

Finally, a peat classification system was developed based on vegetation type, total organic carbon content, maceral analysis, and salinity indicators.

Integration of Paleoenvironmental Analyses

Integration of the paleoenvironmental analyses is summarized and graphically presented for cores SWLA4, SWLA3, and SM08 in Figures 41, 42, and 43. These figures contain a summary of the (a) visual description of sedimentary type, (b) vegetation from the seed analysis, (c) T.O.C.,

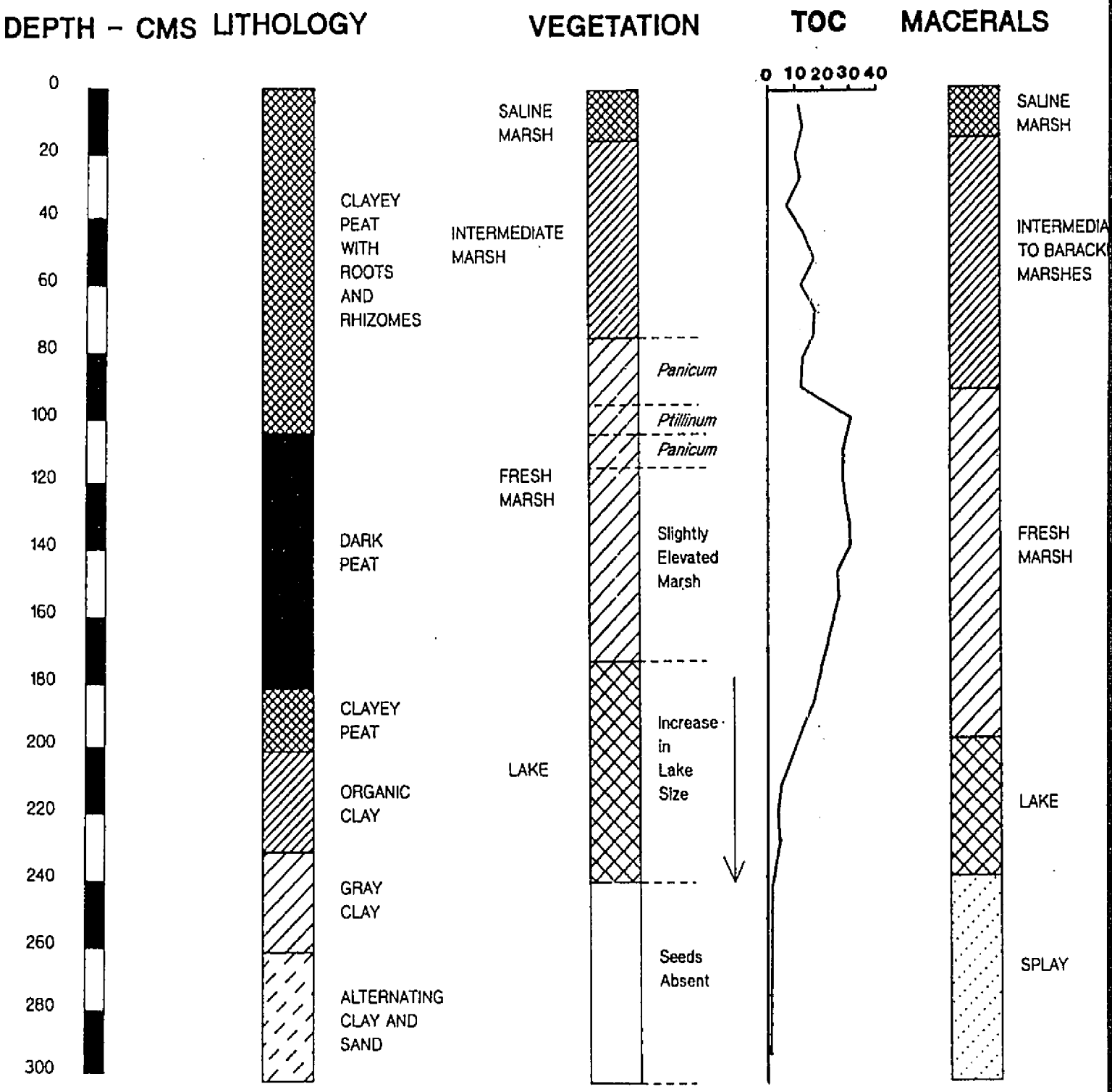
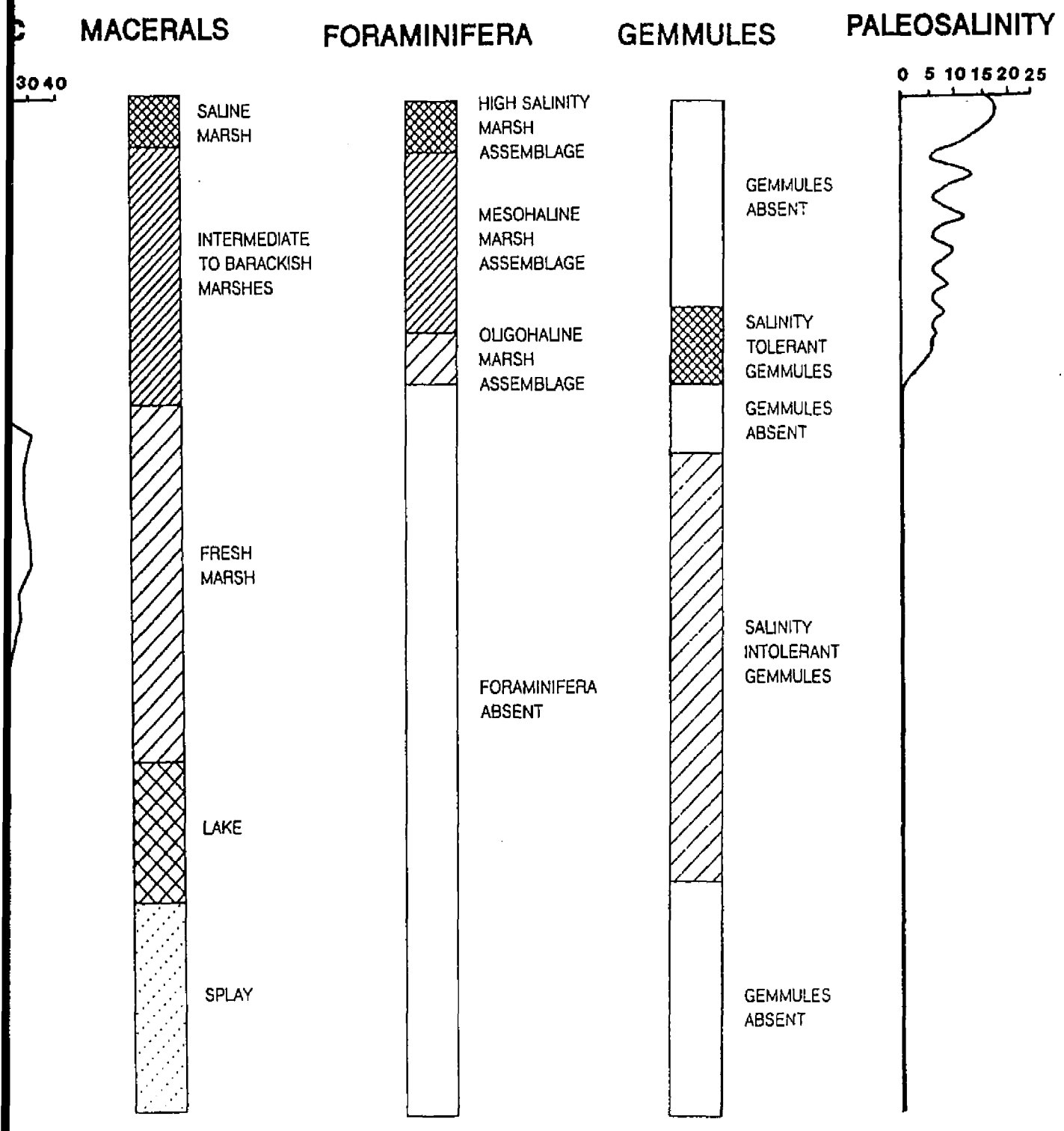


FIGURE 41. Review of Paleoenvironmental and Organic Mat



hental and Organic Matter Analyses for Core SWLA4.

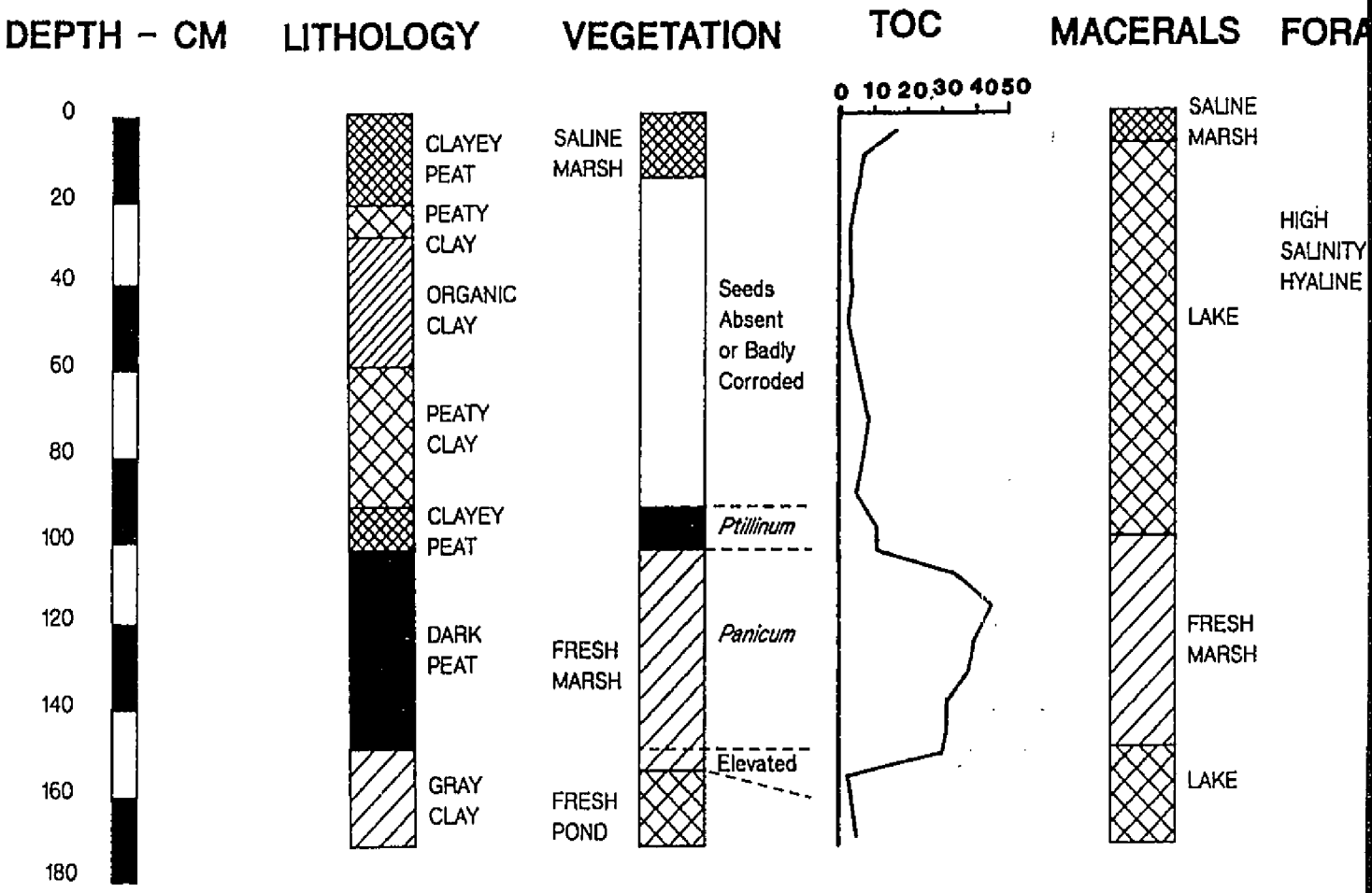
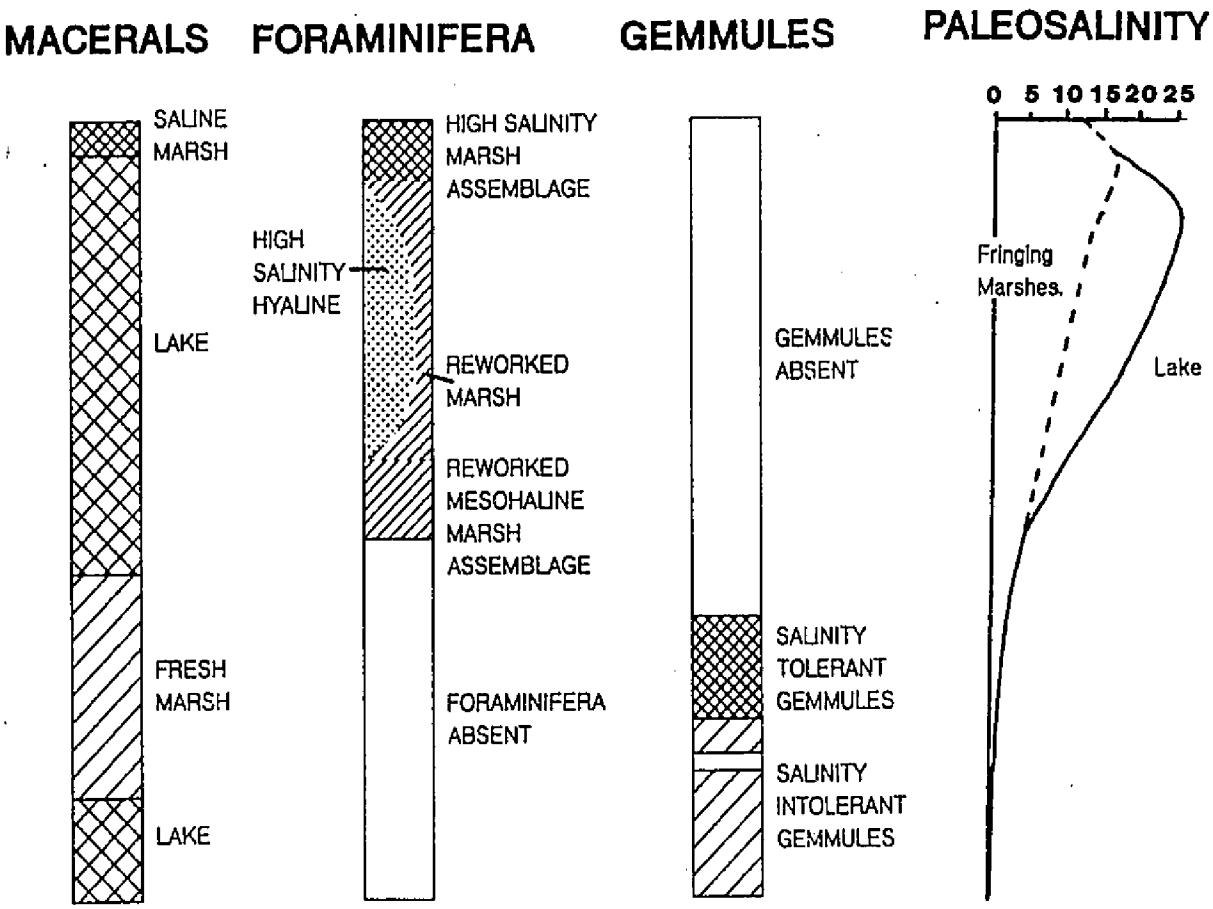


FIGURE 42. Review of Paleoenvironmental and Organic Matte



l and Organic Matter Analyses for Core SWLA3.

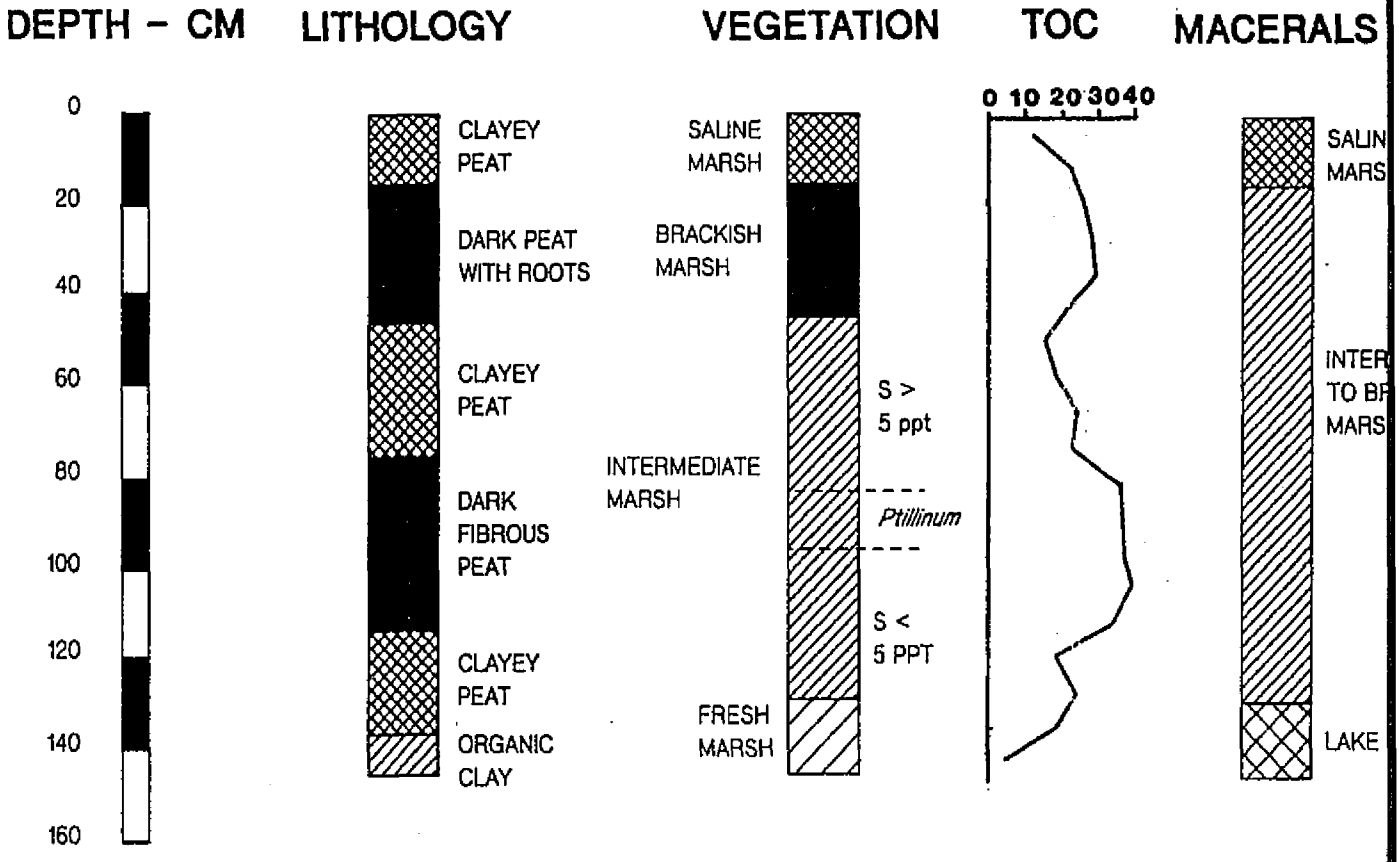
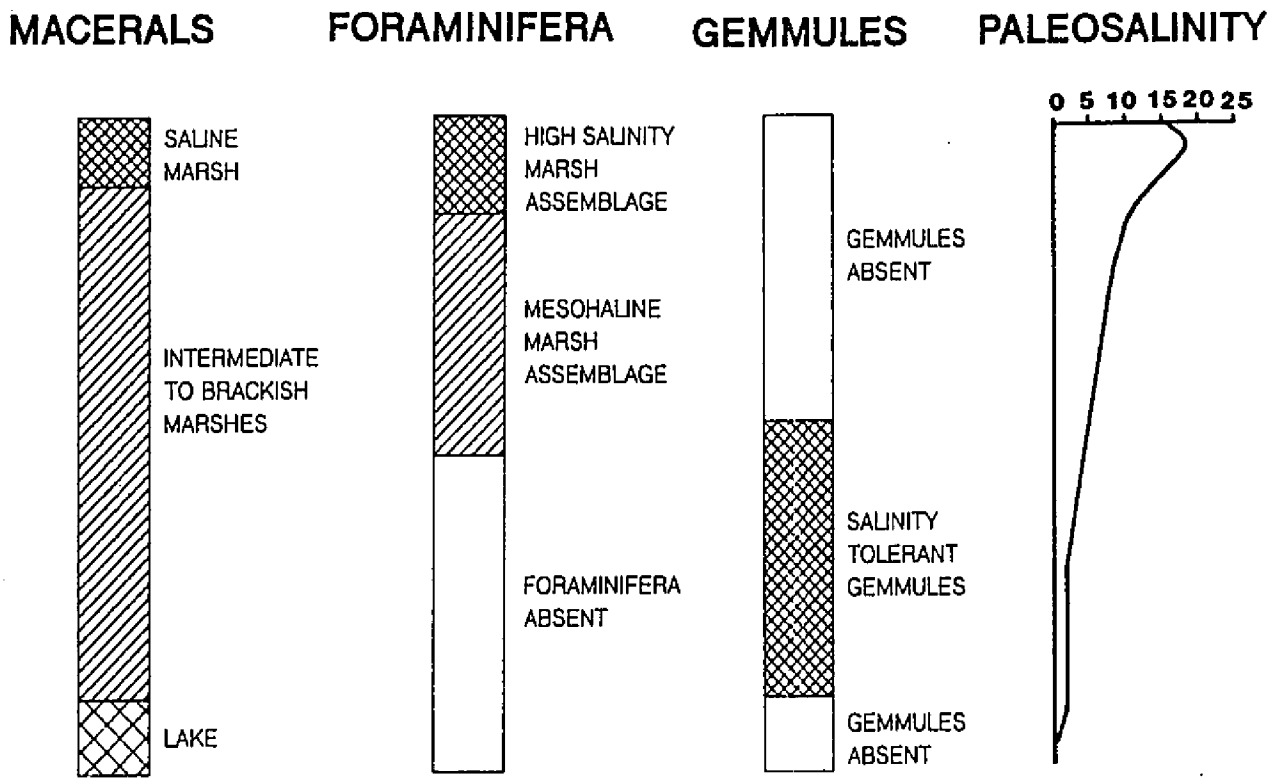


FIGURE 43. Review of Paleoenvironmental and Organic Matt



Organic Matter Analyses for Core SM08.

(d) maceral classification from the cluster analysis, (e) foraminifera zonations, (f) gemmule zonations, and (g) paleosalinity.

The history of each core is discussed in terms of these paleoenvironmental indicators. An integrated description of each core follows.

SWLA4

SWLA4 was the longest core recovered and contained the most complete sedimentary record of the Lafourche delta. The basal sediments (302 to 241 cm) consisted of alternating layers of silty-clays and sands, and was barren of recognizable fossil remains as seeds, foraminifera, or gemmules. Total organic carbon contents were low (less than 1%). Paleoenvironmental analysis was determined through examination of sedimentology and maceral assemblages. The maceral assemblages were indicative of organic matter deposited by hydrodynamic sorting of recycled and reworked higher plant fragments. The presence of darkly colored spores and cuticles indicated some contribution from recycled, ancient sediments. According to the available sedimentary and maceral data, the proposed environment of deposition for the basal sediments is crevasse-splays.

Overlying the splay deposits were 61 cm of clayey sediments. The seed profile represented a freshwater submerged community occupying a lacustrine environment. In addition, changes in the community structure of the submerged floral seed assemblages through time indicated an overall reduction in the size of the lake. This is corroborated by the steadily increasing T.O.C. contents of the sediments up core, due to the infilling of the lake with organic-rich sediments. Totally fresh water conditions during this depositional phase were determined by analyzing the gemmule assemblages. Two maceral cluster assemblages were encountered in this section. The lower two-thirds of the section contained maceral assemblages indicative of a lake environment. The phytoclast macerals examined exhibited signs of aerobic degradation. In addition, an algal component (protistoclasts) comprised a minor portion of the organic matter. The upper one-third of the section contained maceral assemblages similar to the fresh marshes (lack of fungally degraded phytoclasts and high abundances of bacterially degraded phytoclasts). Therefore, the upper section represented a transition environment between the dwindling pond and the true fresh marsh.

Fresh marsh vegetation (determined by the seed assemblage) first appeared at 175 cm and continued to 104 cm. These peats contained the highest organic carbon contents of the entire core. The water, as determined from the

gemmule assemblage, was totally fresh throughout the interval. A radiocarbon date at the base of this interval placed the onset of deposition at 1700 yrs B.P. A radiocarbon date at the top of this interval placed the end of this depositional phase at 800 yrs B.P. Maceral analysis revealed organic matter typical of fresh marsh peats.

Between 104 and 97 cm the floral community suddenly changed due to the presence of *Ptilimnium nutalli* and *Cladium jamaicense* seeds. Gemmules and foraminifera were absent in this interval; however, salinity was deduced from the assemblages below and above the interval. Fresh conditions existed at the base of the interval, while salinities around 5 ppt occurred at the top. Therefore, during this short depositional interval, salinity changed from 0 to 5 ppt, indicating a rapid intrusion of saline water. The maceral assemblages within this interval were indicative of a fresh marsh.

The floral assemblages from 97 to 78 cm indicated a mixture of fresh marsh vegetation and salinity-tolerant intermediate marsh species. Paleosalinity analyses from both gemmules and foraminifera indicated salinities around 5 ppt. The total organic carbon content of these peats sharply decreased from the underlying fresh marsh peats. The maceral assemblage was most similar to the intermediate-brackish marsh cluster.

Clayey peats of relatively low organic contents occurred in the interval from 78 to 15 cm. The vegetation in this interval consisted of species occurring in both brackish and fresh marshes, having the ability to tolerate a relatively wide range in salinity. Therefore, the interval was florally assigned to the intermediate marsh. Paleosalinity determinations from the foraminifera assemblages indicated a general salinity increase through the interval. However, the foraminifera assemblages also indicated the occurrence of frequent periods of low salinity (5 ppt), decreasing in frequency and duration through time. The maceral assemblages clustered with the intermediate-brackish marshes.

Saline marsh deposits in the top 15 cm of the core sharply overlaid the intermediate marsh peats. This material was deposited under relatively high and stable salinities, approximating 15 ppt. Total organic carbon content within the interval was low as compared to that of the the other marsh types. Maceral analysis revealed the presence of fungally attacked organic matter indicative of oxidative conditions. In addition, there was a substantial input of particulate humate organic matter derived from flocculation by sea water.

SWLA3

SWLA3 was recovered from the same interdistributary basin as SWLA4, but more proximal to the eastern distributary channel. Splay-derived sediments were not encountered in the core; however, augered holes revealed splay derived sediments at deeper depths.

The first organic sediments encountered in the core (175 - 157 cm) were deposited in a freshwater pond environment as determined by a seed assemblage representing a submerged fresh water community. Total organic carbon content in this interval was relatively low (between 2 and 5%). The maceral analysis revealed the organic matter in the sediments to be typical of other lake environments (moderately oxidized higher plant matter and a moderate algal component).

At 157 cm, a sharp sedimentary contact existed between the organic poor lake deposits (T.O.C. ~ 3%), and the overlying highly organic fresh marsh peats (T.O.C. ~ 30%). A radiocarbon date of 1000 yrs B.P. was determined on the basal peat at the contact. The dark peat deposits, formed in fresh marshes, continued to 104 cm, exhibiting very high T.O.C. contents of 40%. The maceral assemblages within this interval were typical of the fresh marsh environment. Paleosalinity determinations based on the gemmule assemblages showed a slight increase in salinity as the

peats accumulated through time. The salinity increased from 0 ppt at the base of the peat to about 2 ppt at the top of the section.

Clayey peats were encountered in the interval between 104 to 94 cm. The clayey peats contained numerous seeds of the species *P. nutalli*, and as in core SWLA4, this assemblage coincided with an abrupt salinity change. The salinity increased from 2 ppt at the base of the interval (104 cm) to over 5 ppt at the top of the interval (94 cm). The maceral assemblage of this interval was most similar to the lake clusters.

The interval between 94 to 15 cm represented sediments deposited in a brackish to saline lake environment. The few seeds recovered from these sediments were badly corroded, indicating transportative degradation. Paleoenvironmental information was provided by the foraminifera assemblages. The base of the interval (94 - 76 cm) contained agglutinated species reworked into the lake sediments from the neighboring oligohaline marshes. From 76 to 38 cm the lake increased in size. This expansion is deduced from the steadily decreasing proportion of agglutinated species in the assemblages up core, and the decreasing total organic carbon contents of the sediments. Maximum areal size of the lake occurred at 38 cm, becoming progressively smaller with time (up core). Reduction in the

size of the lake was determined by the increase in the proportion of marsh agglutinated species through time, and increases in the organic carbon content of the sediments. Salinities at the sediment-water interface of the lake increased in this interval (76 - 38 cm). This salinity increase occurred from the combined effects of the reduction in lake size and the regional salinity intrusion.

The foraminifera assemblage distribution of the reworked agglutinated species also recorded a general salinity increase occurring in the neighboring marshes. A depth salinity profile of the lake sediments (solid line) and the marsh sediments (hatched line) are presented in Figure 42.

Saline marsh peats were deposited in the top 15 cm of the core. The maceral assemblages, moderate total organic carbon contents, and foraminifera assemblages, were all indicative of a saline marsh.

Core SM08

Core SM08 was recovered from an interdistributary basin proximal to Caminada Bay. The rationale for studying this core was to ascertain the extent of inter-basinal paleoenvironmental events.

The basal deposits of the core (150 - 130 cm) contained seeds representative of a fresh marsh of low species diversity. A sudden increase in the total organic carbon content of the sediments within the interval suggested a transition from a fresh pond to a fresh marsh. The maceral assemblages of the sediments within the interval were most similar to the lake clusters.

Dark fibrous peats and clayey peats were recovered in the interval between 130 to 46 cm. The paleoenvironmental analysis by seeds indicated deposition in an intermediate marsh environment. A radiocarbon date at the base of the peat indicated initiation of the intermediate marsh deposition at 870 yrs B.P. Intermediate marsh deposits were divided into two sub-units. The lower sub-unit (130 - 76 cm) contained typical intermediate marsh floral assemblages. Gemmule assemblages indicated that these sediments were not subjected to salinities over 5 ppt. Lower intermediate marsh deposits contained very high total organic carbon contents (40%). The upper intermediate marsh sub-unit extended from 76 to 45 cm and was florally characterized by monospecific occurrences of *Cyperus odoratus*. Total organic carbon content of these sediments was markedly less than that of the lower sub-unit. Paleosalinity, as determined from the foraminifera assemblages, was above 5 ppt throughout the sub-unit. Maceral analysis indicated

that both sub-units contained maceral assemblages most similar to the intermediate-brackish marsh clusters.

Brackish marsh peats were deposited during the interval from 46 to 15 cm, exhibiting markedly higher total organic carbon contents as compared to the underlying intermediate marsh interval. Paleosalinities during the deposition of the brackish marshes ranged from 5 ppt at the base to approximately 12 ppt at the top of the interval (15 cm).

The top 15 cm of the core represented deposition within a saline marsh environment. Total organic carbon contents of the saline marsh deposits were lower than the underlying brackish marshes. Paleosalinity of the marsh environment was approximately 18 ppt.

Effects of Environmental Factors on Peat Type and Quality

The previous section detailed the historical development of each core in terms of vegetation, salinity, and peat quality (T.O.C. and maceral content). The data were used in this section to deduce certain processes controlling peat formation within a deltaic setting.

Salinity effects

The most pronounced paleoenvironmental changes in each core were an increase in salinity through time. This increase in salinity was the major factor controlling the type and quality of the peat deposits. All three study cores recorded a general progression from fresh marsh peats towards the basal sections of the cores to saline marsh deposits at the surface. However, the greatest differences between the cores existed in the presence, extent, and quality of the intermediate and brackish marsh deposits.

The nature of these mesohaline-influenced brackish and intermediate marsh peats was highly dependent on the stability and intensity of salinity. Deltaic abandonments were not sudden events and, as in the case of the Lafourche delta, freshwater input to the basin gradually decreased over the course of centuries. In recognition of the highly dynamic salinity regime of deltaic environments, and the coupling of marsh type to salinity, a discussion of salinity-induced marsh changes follows.

Fossil groups encountered in this study represented organisms that responded differently to the duration and intensity of salinity. Gemmules (sponges) and foraminifera were sensitive to relatively short-term salinity changes. The salinity sensitivity of these organisms may have been as short as seasonal. For this reason, salinity-induced

changes in the foraminifera and gemmule assemblages are defined as short-term salinity indicators. Conversely, plant communities (marsh types) may not respond to subtle salinity changes of short duration. The response time for salinity-induced marsh type changes may be on the order of decades. Vegetative changes in marsh type are therefore long-term salinity indicators. These higher plant communities may be able to withstand minor seasonal fluctuations in salinity. However, the cumulative effects of salinity variations may ultimately control the nature of the plant community. Therefore, a measure of average salinity over a certain time does not entirely describe the effect of salinity on the plant community. The variability and range of salinity changes must also be considered when determining the salinity effect on the floral composition of a peat.

The relationship between paleosalinity and marsh type in the brackish and intermediate marsh peats of cores SWLA4 and SM08 illustrates the aforementioned concepts. The intervals between 76 and 15 cm in both cores were subjected to almost identical <u>average</u> salinity regimes. Foraminifera assemblages suggested salinities of 5 ppt at the base of the sections, increasing to about 12 ppt at the top of the sections. However, the salinity increase in core SM08 was smooth compared to the widely fluctuating and highly variable salinity increase over the same interval in core

SWLA4. The salinity fluctuations in core SWLA4 are hypothesized to occur from episodical discharges of fresh water from the waning Lafourche distributary. These discharges resulted in temporary periods of low salnity (~ 5 ppt), decreasing in frequency and duration through time (up core). Core SM08 was farther from the source of the freshwater discharge and was not subjected to low salinity.

The effect of the two salinity histories on the type and quality of the peat was dramatic. The steady salinity increase in core SM08 induced a marsh type change from intermediate to brackish. Total organic carbon contents of these peats were relatively high (~ 30%). Conversely, the erratic salinity increase in core SWLA4 repressed the change from the intermediate to brackish marsh. Plant species existing during this time interval were able to withstand fluctuating salinities. Additionally, low organic carbon contents of these deposits indicated low organic productivity, possibly resulting from the stresses imposed by the fluctuating salinities.

Therefore, salinity variability, as well as average salinity, must be incorporated into the analysis of the environmental effects on peat typology. It was demonstrated in this study that salinity fluctuations may repress floral changes and lower organic productivity.

Average salinity change may also affect peat quality within a marsh type. Core SM08 contained two distinct intermediate marsh sub-types. The lower intermediate marsh sub-type (130 - 76 cm) was subjected to average salinities < 5 ppt, consisting of very organic peats (T.O.C. 40%). The upper sub-unit (76 - 46 cm) was subjected to salinities approximating 5 ppt, and containing substantially lower organic sediments (T.O.C. 20%). In the case of the upper sub-unit, the salinity was not high enough to activate a marsh type change, but high enough to cause a stressed environment resulting in lower organic productivity. Organic production increased in the overlying brackish marsh peats once the salinity was high enough to activate a marsh type change.

Salinity may also directly affect the type of organic matter deposited as a peat. As discussed in a previous section, maceral analysis can depict the nature and sources of organic matter deposition and preservation in sedimentary systems. A salinity effect was determined to control the deposition of the amorphous infested indeterminate (A.I.I.) maceral type in the peats. As salinity increased, the A.I.I maceral became a larger component of the peats' organic content. The A.I.I. maceral in peats is hypothesized to consist of precipitated humates. Salinity affects the deposition of the particulate humate organics (A.I.I. macerals) by controlling the proportion of fresh water

(rich in dissolved humates) to normal marine saline water (high flocculating ability). Therefore, as marsh habitats become more saline, higher proportions of the organic matter in the peats are derived from precipitated humates.

Water depth

Water depth is the second most important variable controlling the distribution of marsh types in the Louisiana peatlands. Successional changes in floral assemblages from open-water environments give rise to true marsh vegetation. The mechanism proceeds by a lowering of water levels through organic and inorganic sedimentary processes.

The successional process of marsh formation occurred in the basal sediments from core SWLA4. Overlying the splay deposits were 61 cm of lake sediments. The vegetation analysis showed a reduction in the size of the lake through time as water depth decreased and the organic content of the sediments increased. Fresh marsh peats began to accumulate when water depth was lowered to the point where true marsh vegetation could exist. Total organic carbon content of the sediments and the seed assemblages documented the lowering of water depth and the transition to the fresh marsh.

Water depth overlying the marsh also affects the quality of the organic matter forming the peat. Shallow water, or even the complete absence of water, allows diffusion of molecular oxygen to the marsh surface. These oxidizing conditions support aerobic fungal and bacterial pathways which more effectively degrade organic matter. This low overlying water depth effect controlled the quality of organic matter deposited in the saline marsh peats of the study cores. These peats contained comparatively larger proportions of fungally derived infested phytoclasts and scleratoclasts. These macerals are indicative of biological oxidative processes. Saline marshes in coastal Louisiana have the lowest overlying water depth of all the marsh types (Penfound and Hathaway, 1938). The lower water depths allowed diffusion of molecular oxygen to the marsh surface, resulting in the observed aerobic degradation and low organic carbon contents. High sedimentation rates and exportation of organic matter in the saline marshes are also contributory factors to the low organic content.

Evolution of an Interdistributary Basin

Core reconstructions summarized in the preceding sections were used in this section to describe the history of a small interdistributary basin formed in the lower portion

of the Lafourche delta. The discussion focuses on the interdistributary basin containing cores SWLA3 and SWLA4, with general comparisons to events occurring throughout the study area. The interdistributary reconstruction utilized auger hole data and paleoenvironmental data from cores SWLA3, SWLA4, and SM08. Radiocarbon dates at selected intervals were used as temporal references.

Analysis of the reconstructed stream channels in the study area revealed several small interdistributary basins. Bayous Lafourche and Ferblanc were the major distributaries, with numerous small channels defining small scale interdistributary basinal environments of the lower delta plain. The described physiographic setting is typical of ancient Mississippi River delta lobes. Unlike the Lafourche system, the Modern birdsfoot delta does not contain extensive channel systems and numerous interdistributary basins. Therefore, the deposits encountered in the present study more closely represent natural deltaic deposits, as opposed to the man-modified physiography of the Modern delta.

Auger and core hole descriptions indicated that each of the small channels depicted in Figure 4 did not exist contemporaneously (as suggested by differences in depths to the tops of the splay deposits). There is a general west to east initiation of stream channels as determined by the

progressive decreasing depth to the tops of the splay deposits.

The largest interdistributary basin in the study area was used in this section as an example of small-scale, lower delta interdistributary basin formation. The paleoenvironmental reconstructions from cores SWLA3 and SWLA4 were the main factors in the reconstruction. The reconstruction is divided into stages depicting distinct phases in the development of the interdistributary basin. These stages are illustrated in Figures 44 and 45.

Stage 1

The first sediments encountered in the proto-basin were interpreted as splay sands and silts overlying finer grained bay deposits. These crevasse splays were derived from the main Lafourche distributary. No true interdistributary environment existed during this stage due to the absence of a secondary channel and levee system in the vicinity of site SWLA5.

Stage 2

The continuing development and progradation of the secondary channel initiated interdistributary basin formation. The reduced input of coarse-grained sediments into the central portions of the basin (SWLA4) from Lafourche,

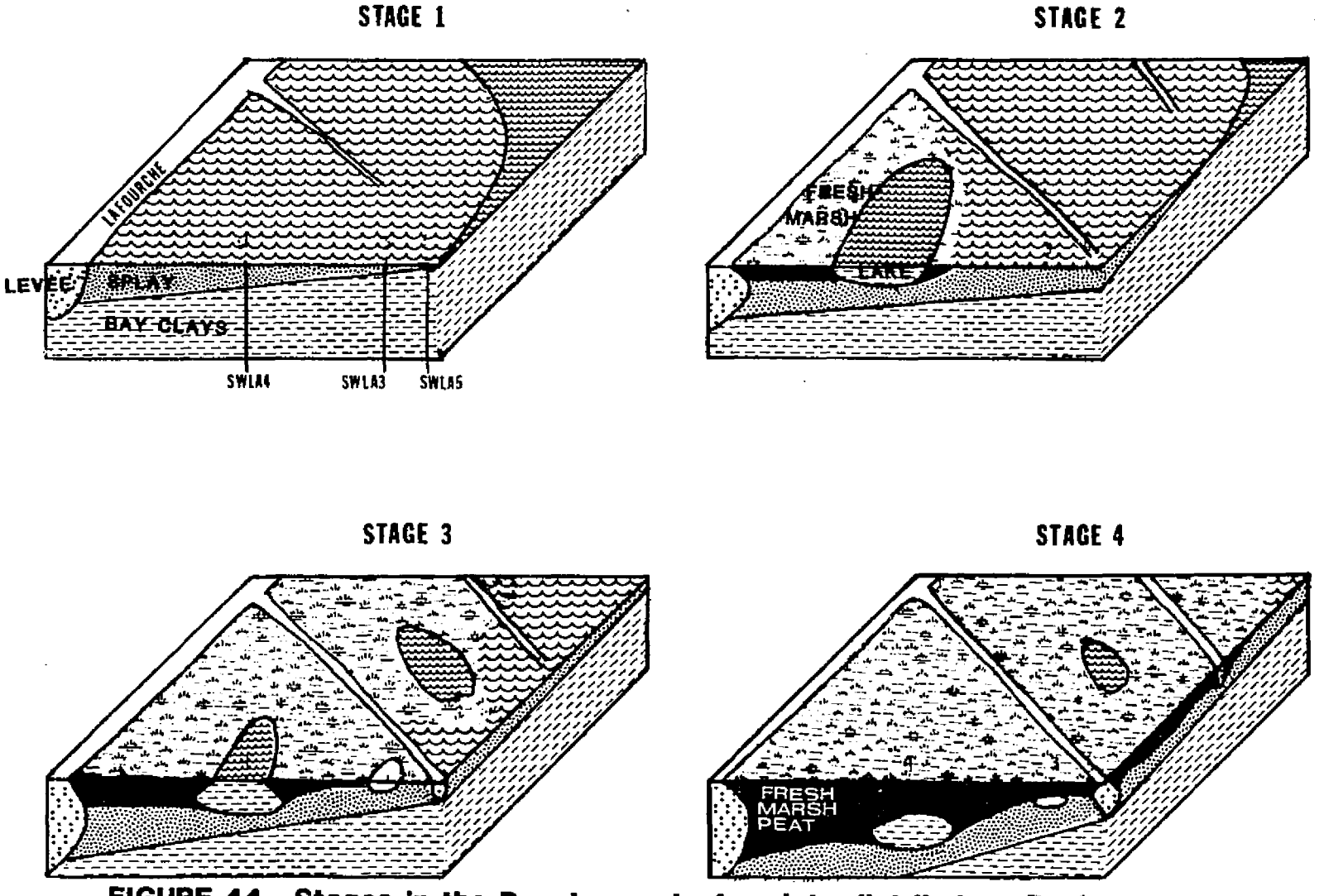
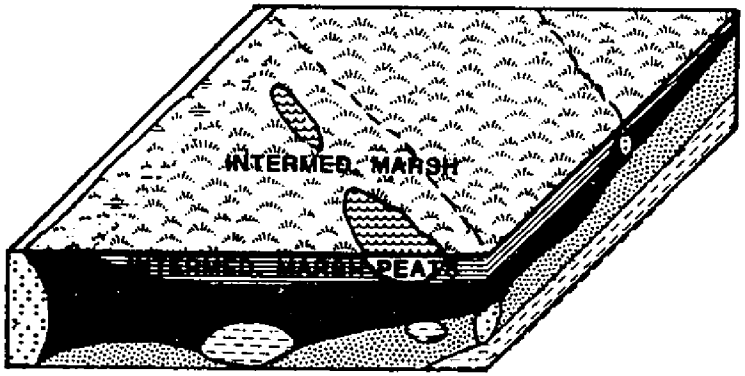


FIGURE 44. Stages in the Development of an Interdistributary Basin.

STAGE 5



STAGE 6

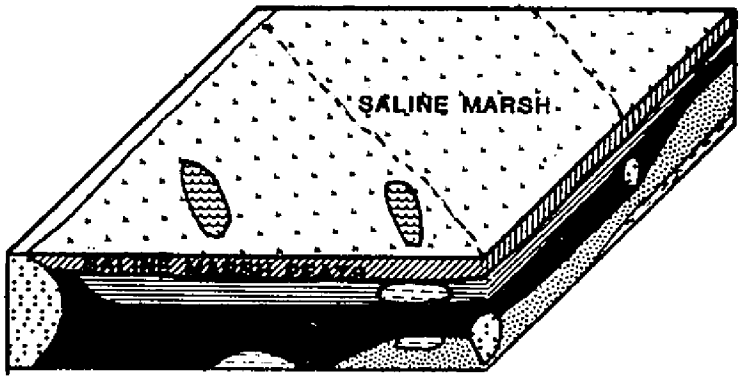


FIGURE 45. Stages in the Development of an Interdistributary Basin (contd.).

in conjunction with continuing subsidence, led to the formation of a central trough. This trough formed a lake environment in the central basin, supporting a floating floral community. Freshwater marsh deposits formed between the lake and the main channel, depositing organically rich sediments into the lake environment. During this stage, splays were still being deposited in the vicinity of the secondary channel at sites SWLA3 and SWLA5.

Stage 3

As the secondary channel completely prograded into the study area, the interdistributary basin no longer received coarse-grained sediments. The major discharge moved to a more easterly located channel, thus forming an adjacent interdistributary basin. Fresh marsh peats formed over the lake deposits in the central basin (SWLA4). Small ponds formed in the vicinity of SWLA3 between the central basin and the secondary channel (SWLA5). Radiocarbon dating of the basal peats in core SWLA4 timed these events at approximately 1700 yrs B.P.

Stage 4

Deposition of fresh marsh peats occurred over the entire basin during this stage. The small pond at SWLA3 was infilled and fresh marsh peats were abruptly deposited over

the organic lean clayey sediments. Thick fresh marsh peat deposits continued to accrete in the central basin at site SWLA4. Radiocarbon dating of the basal peats in core SWLA3 indicate initiation of these events approximately 930 years B.P.

Stage 5

Reduction of freshwater input to the interdistributary basin resulted in an overall salinity increase. This resulted in the formation and accretion of intermediate marsh peats at SWLA4. The salinity increase during this stage was gradual and characterized by frequent pulses of fresh water. Paleoenvironmental analyses from core SM08 also indicated increasing salinity in that interdistributary basin.

Within this time interval a brackish lake formed at site SWLA3. The levee deposits at site SWLA5 had completely subsided and were overlaid by intermediate marshes.

Stage 6

The last stage in the evolution of the interdistributary basin involved a very sudden salinity increase. This is evident from the foraminifera assemblages and vegetation reconstructions from all three study cores. The saline marsh peats in core SWLA4 directly overlaid the

intermediate marsh peats unseparated by a brackish marsh. At present, these widespread saline marsh peats blanket the entire study area.

The sudden salinity increase and the formation of saline marshes were partially a result of the artificial closing of Bayou Lafourche in 1904. Therefore, marsh accretion during this stage reflected artificially induced, man-made modifications of the wetland environment. It is outside the scope of this study to ascertain the beneficial or detrimental effects of this modification on peat accretionary processes.

Peat Classification Scheme

The previous sections demonstrated that peat formation and accumulation in Louisiana marshlands are integrally coupled to deltaic processes. Since deltaic processes are areally and temporally dynamic, peat formation is controlled by non-stable and transitory environmental factors.

Existing classification systems categorize peats by vegetation type and organic matter quality. Vegetation type and organic matter quality are controlled by environmental conditions. Therefore, a peat classification system should include descriptions of the environmental conditions that existed during deposition.

The peat classification system proposed in this study incorporates standard descriptive criteria with the environmental indicators previously developed (maceral analysis and fossil salinity parameters). This classification system can be used for both Recent and buried peat deposits. Therefore, the purpose of this exercise was to establish a process oriented classification system, and to demonstrate how this system can more fully describe peat deposits.

The classification system utilizes four categorical descriptors:

(1) vegetation type

(2) total organic carbon content

(3) maceral analysis parameters

(4) salinity analysis

A discussion of each descriptor and its utility in the peat system follows.

Vegetation type

Vegetation type is the most important parameter in the system since it describes the contribution of the plant species forming the peat. Plant associations yield valuable information regarding the environmental conditions that existed during formation of the peat.

Vegetation type can be described on the basis of known plant associations (i.e., saline marsh peat, brackish marsh peat, etc.). More detailed classifications can utilize the dominant floral constituents (e.g., *Spartina alterniflora* peat, *Distichlis-Juncus* peat).

The vegetation type is determined by the existing floral assemblage in the case of Recent peats, or by the seed assemblage in the case of buried peats.

Total organic carbon content

The quantity of organic matter in a peat defines (to a certain extent) the efficiency of the peat forming process. For example, highly organic peats are the product of environmental factors such as low sedimentation rates, high productivity, low organic exportation, and high preservation. Several of these environmental factors are interrelated and act collectively to produce a high organic peat. Therefore, the overall efficiency of the peat forming process is reflected in the total organic carbon content.

Total organic carbon (T.O.C.) produces a numerical value which can be further reduced to discrete (ordinal) categories (e.g., 10-20%, 20-30%, 30-40%, etc.). In the absence of total organic carbon measurements, a subjective

assessment of organic matter quantity can be made by visual inspection of the peat.

Maceral analysis parameters (organic matter quality)

As discussed in a previous section, maceral analysis is a quantitative analysis of sedimentary organic matter as to type, degradation state, and thermal alteration. It was demonstrated that maceral assemblages of peats can be used to classify and elucidate certain environmental factors affecting organic matter quality.

For this peat classification scheme, several indices derived from the maceral assemblage were used as categorical criteria.

1. Type of organic matter

(a) A measure of the total number of phytoclasts to the total number of protistoclasts in a sample yields a general index of the contribution of organic matter from higher plant vs. algae. The source of organic matter in peats is predominantly higher plant; however, algae may contribute some organic matter to certain peat types.

(b) The proportion of amorphous infested indeterminate macerals in a peat represents organic matter derived from the flocculation of dissolved organic matter (humates). The proportion of amorphous infested indeterminate macerals to

the total number of macerals is an indication of the magnitude of this process.

2. Degradation state

(a) Maceral analysis is particularly powerful for determining the nature and extent of biodegradation. Recognizing the presence and extent of aerobic biodegradation is of particular importance to peat studies. A measure of the extent of oxidative biodegradation can be accomplished using maceral analysis, assuming fungally attacked organic matter is an indication of aerobic degradation. The biodegradation index is the ratio of the bacterially degraded macerals (amorphous structured, amorphous unstructured, and amorphous infested phytoclasts) to the fungally degraded macerals (poorly structured and infested phytoclasts, and scleratoclasts).

The index for the peats in this study ranged between .35 to 3.83. Low values (< 1.00) were indicative of periodically oxidizing conditions. Biodegradation indices between 1 and 2 indicated mildly oxidizing to reducing conditions. High values (> 2.00) indicated reducing conditions throughout the depositional and early diagenetic history of the peat.

Salinity

Salinity is the most important factor controlling the type of vegetation comprising peat deposits in coastal Louisiana. In addition, the salinity of the overlying marsh water affects the types of organic matter deposited into the peats.

It was demonstrated in previous sections that marsh salinities may be highly variable over relatively short time periods. Therefore, measurements of salinity at the time of field sampling do not characterize the total salinity effect on the peat.

Analyses using the salinity distribution of biota provide more accurate measures of the magnitude and variability in salinity during peat deposition. These biotic indicators can be used to supplement measured salinities in Recent studies, and must be used for studying ancient peats. Paleosalinity measurements on sub-surface deposits using chemical indicators should be avoided due to migration of water-soluble chemical species.

In this study, the foraminifera and gemmule assemblages accurately described the magnitude and variability in paleosalinity. The categorization scheme presented in this section utilizes these fossil organisms to measure average salinity as well as variations in

salinity. Relationships of salinity to the fossil assemblages were presented in previous sections.

It is suggested that this peat classification system be adopted in future peat studies. The process-oriented approach substantially increases the information derived from peat studies. A review of the proposed peat classification parameters is presented in Tables V and VI.

TABLE V. PEAT CLASSIFICATION SCHEME PART I

VEGETATION TYPE *

a) Peat Type

egs. saline marsh
brackish marsh
intermediate marsh
fresh marsh
fresh swamp

or

b) Species Composition

egs. *Spartina alterniflora* marsh
Distichlis-juncus marsh

* For surface peats the living species composition can be used. For buried peats the seed assemblage is necessary.

ORGANIC MATTER QUALITY

a) Total Organic Carbon

1. numerical value
2. ordinal measurement
   egs. 0–10%, 10–20%, etc.

or

b) Visual Description

egs. peat, clayey peat, fibric, etc.

SALINITY

a) Salinity > 5, Foraminifera

a) measure of average salinity
b) measure of variability in salinity

b) Salinity < 5, Gemmules

a) measure of average salinity

c) Field Measurements

TABLE VI. PEAT CLASSIFICATION SCHEME PART II

ORGANIC MATTER QUALITY

MACERAL ASSEMBLAGE

a) Type of Organic Matter

1) ratio of higher plant to algal sources (HP/A)

$$HP/A = \frac{\text{phytoclasts}}{\text{protistoclasts}}$$

2) contributions from precipitated humates (P.H.)

$$P.H. = \frac{\text{amorphous infested indeterminate}}{\text{total maceral count}}$$

b) Degradation State

ratio of anoxic derived macerals to aerobically derived macerals (D.S.)
(based on phytoclasts and scleratoclasts)

$$D.S. = \frac{\text{(amorphus str.+amorphous unstr.+amorphous infested)}}{\text{(poorly str.+infested+scleratoclasts)}}$$

D.S. < 1	oxidizing conditions
D.S. 1 to 2	mildly oxidizing conditions
D.S. > 2	reducing conditions

REFERENCES

Adams, D.A. (1963) Factors influencing vascular plant zonation in North Carolina salt marshes: Ecology, vol. 44, no.3, pp. 445-456.

Alpern, B. (1970) Classification petrographique des constituants organiques fossiles des roches sedimentaires: Rev. Inst. franc. Petrole, 25, 11, pp. 1233-1266.

Argus, G.W. and M.B. Davis (1962) Macrofossils from a late-glacial deposit at Cambridge, Massachusetts: Am. Midland Naturalist, vol. 67, pp. 106-117.

Baker, R.G. (1965) Late-glacial pollen and plant macrofossils from Spider Creek, southern St. Louis County, Minnesota: G.S.A. vol. 76, pp. 601-610.

Beijerinck, W. (1947) Zadenatlas Der Nederlanshe Flora Ten Behoeve Van De Botanie, Paleontologie, Bodecultuur en Waren Kennis: H. Veenman and Zonen Wagenigen, 316 pp.

Berggren, G. (1969) Atlas of Seeds and Small Fruits of Northwest-European Plant Species. Part 2. Cyperacea.: Berligska Boktryckeriet, 68 pp.

Brown, C. (1948) Observations on the vegetation in the vicinity of Barataria Bay and the Texas oil field near Lafitte, Louisiana: Texas A and M Univ., Res. Found. Proj. 9.

Bujak, J.P., M.S. Barss, and G.L. Williams (1977) Offshore east Cananada's organic type and color and hydrocarbon potential: Oil and Gas Journal, April 4, pp. 199-202.

Burgess, J.D. (1974) Microscopic examination of kerogen (dispersed organic matter) in petroleum exploration: G.S.A. Special Paper 153, pp. 19-30.

Byrne, J.V., D.O. Leroy, and C.M. Riley (1959) The Chenier Plain and its stratigraphy southwestern Louisiana: Gulf Coast Assoc. of Geologocal Soc. Trans., vol. 9, pp. 237-260.

Cain, S.A. (1939) Pollen analysis as a paleo-ecological research method: The Botanical Review, vol V, no. 12, pp. 627-654.

Cann, J.H. and P. DeDeckker (1981) Fossil Quartenary and living Foraminifera from athalassic (non-marine) saline lakes southern Australia: Journal of Paleontology, vol. 55, no. 3, pp. 660-670.

Cassagrande, D.J., G. Idowu, and A. Friedman, P. Rickert, K. Siefert, and D. Schelnz (1979) H_2S incorporation in coal precursors: origins of organic sulphur in coal: Nature, vol. 282, pp. 599-600.

Cassagrande, D.L. and L. Ng (1979) Incorporation of elemental sulphur in coal as organic sulphur: Nature, vol. 282, pp. 598-599.

Cassagrande D.J., K. Gronli, and N. Sutton (1980) The distribution of sulfur and organic matter in various fractions of peat: origins of sulfur in coal: Geochimica et Cosmochimica Acta, vol. 44, pp. 25-32.

Chabreck, R.H. (1972) Vegetation, water, and soil characteristics of the Louisiana coastal region: Louisiana Agricultural Experiment Station Bulletin no. 664.

Chabreck, R.H. and R.E. Condrey (1979) Common vascular plants of the Louisiana marsh: Sea Grant Publication No. LSU-T-79-03 Louisiana State University Center for Wetland Resources, Baton Rouge, LA.

Cohen, A.D. (1968) The petrology of some peats of southern Florida (with special reference to the origin of coal) [PhD thesis]: University Park, Penn. State Univ., 352 pp.

Cohen, A.D. (1973) Petrology of some Holocene peat sediments from the Okefenokee swamp-marsh complex of southern Georgia: G.S.A. Bull., vol. 84, pp. 3667-3878.

Cohen, A.D. and W. Spackman (1972) Methods in peat petrology and their application to reconstruction of paleoenvironments: G.S.A. Bull., vol. 83, pp. 129-142.

Coleman, J.M. (1966) Recent coastal sedimentation: central Louisiana coast: Coastal Studies Institute Tech. Report No. 29, L.S.U. Baton Rouge, LA.

Coleman, J.M. and S.M. Gagliano (1964) Cyclic sedimentation in the Mississippi River deltaic plain: Trans. Gulf Coast Assoc. Geol. Soc., vol. 14, pp. 67-80.

Coleman, J.M. and S.M. Gagliano (1965) Sedimentary structures- Mississippi delta plain: In G.V. Middleton, ed., Primary Sedimentary Structures and Their Hydrodynamic Interpretation - A Symposium, Soc. Econ. Paleon. And Mineral., Special Publication 12, pp. 133-148.

Darrell, J.H. and G.F. Hart (1970) Environmental determinations using absolute miospore frequency, Mississippi River delta: G.S.A. Bull., vol. 81, pp. 2513-2518.

Drever, J.I. (1971) Early diagenesis of clay minerals, Rio Ameca basin, Mexico: J. Sediment. Petrol. vol. 41, pp. 982-995.

Eggler, W.A. (1961) Louisiana coastal marsh ecology: Coastal Studies Inst. Contr. No. 61-2, Report 14, Louisana State University, Baton Rouge, LA.

Ellison, R.L. (1972) *Ammobaculites*, foraminiferal proprietor of Chesapeake Bay estuaries: G.S.A. Memoir No. 133, pp. 247-262.

Faegeri, K. and J. Iversen (1975) Textbook of Pollen Analysis 3rd edition, Hafner Press, New York, 295 pp.

Farnham, R.S. (1963) Classification of peat in the U.S.A.: 2nd Int. Peat Congress, Trans. vol. 1, Leningrad USSR, pp. 115-132.

Fassett, N.C. (1969) A Manual of Aquatic Plants, The University of Wisconsin Press, Madison, Milwaukee, London, 405 pp.

Fisk, H.N. (1955) Sand facies of Recent Mississippi delta deposits: Proc. 4th World Pet. Cong., Sec. 1, pp. 377-398.

Fisk, H.N., E. McFarlan, C.R. Kolb, and L.J. Wilbert, (1954) Sedimentary framework of the Modern Mississippi delta: Journal of Sedimentary Petrology, vol. 24, pp. 76-99

Frazier, D.E. (1967) Recent deltaic deposits of Mississippi River: The development and chronology: Amer. Assoc. Petrol. Geol. Bull., 51(10)

Frazier, D.E. and A. Osanik (1969) Recent peat deposits, Louisiana coastal plain: In E. Daples and M. Hopkins (eds.) Environments of Coastal Deposition, G.S.A. Spec. Paper 114.

Gray, J. and H.J. Boucot (1975) Color changes in pollen and spores: A review: G.S.A. Bull., vol. 86, pp. 1019-1033.

Gould, H.R. (1970) The Mississippi delta complex: In J.P. Morgan, ed., Deltaic Sedimentation Modern and Ancient, S.E.P.M. Special Publ. No. 15, pp. 3-30.

Hart, G.F. (1979a) Maceral and geochemical analyses of Mississippi deltaic plain environments. Hartax International Bulletin No. 2.

Hart, G.F. (1979b) Maceral analysis and its applications in petroleum exploration: ABS. In: Petroleum Potential in Island Archs, Small Ocean Basins, Submerged Margins, and Related Areas, United Nations Development Programme, Suva, Fiji, pp. 32-33.

Hitchcock, A.S. (1950) Manual of the Grasses of the United States 2nd edition, U.S. Dept. Agr. Misc. Publ. 200.

Ho, C.L., R.E. Turner, and T. Whelan (1976) Diagenesis of Recent peat deposits: Annual Report 1975-1976, Costal Studies Institute Louisana State University, Baton Rouge, LA.

Hotchkiss, M. (1970) Common Marsh, Underwater and Floating Leaved Plants of the U.S. and Canada, Dover Publications, New York.

Kolb, C.R. and J.R. Van Lopik (1966) Depositional environments of the Mississippi River deltaic plain, southeastern Louisiana: In M.L. Shirley and J.A. Ragsdale (eds.), Deltas, pp. 17-62: Houston, Texas Geological Society.

Kruit, C. (1955) Sediments of the Rhone delta. Part I, Grain size and microfauna: Koninkl Nederlandsche Geol. Mijnb. Genoot. Geol. Ser. 15, pt. 3, pp. 352-499.

Krumbein, W.C. and E. Aberdeen (1937) The sediments of Barataria Bay: Journal of Sedimentary Petrology, vol. 7, pp. 3-17.

Lee, J.J. (1974) Towards understanding the niche of the Foraminifera: In Hedley, R.H. and C.G. Adams (eds.), Foraminifera, vol. 1 pp. 207-260, Academic Press, London.

Lord, C.J. (1980) The chemistry and cycling of Iron, Manganese, and Sulfur in salt marsh sediments: Unpubl. PhD Dissertation, University of Delaware, 177 pp.

MacFarlane, R.B. (1978) Molecular weight distribution of humic and fulvic acids of sediments from a north Florida estuary: Geochimica et Cosmochimica Acta, vol 42, pp. 1579-1582.

Martin, A.C. and W.D. Barkley (1961) Seed Identification Manual: University of California Press, Berkley and Los Angeles, 221 pp.

Martin, P.S. and J. Gray (1962) Pollen analysis and the Cenozoic: Science, vol. 137, No. 3524, pp. 103-111.

Mason, H.L. (1957) A Flora of the Marshes of California: University of California Press, Berkley and Los Angeles.

Matera, N.J. and J.H. Lee (1972) Environmental factors affecting the standing crop of foraminifera in sublittoral and psammolittoral communities of a Long Island salt marsh: Marine Biology, vol. 14, pp. 89-103.

McCrone, A.W. and C. Schafer (1966) Geochemical and sedimentary environments of foraminifera in the Hudson River estuary, New York: Micropaleontology, vol. 12, No. 4, pp. 505-509.

Miller, W.R. and F.E. Egler (1950) Vegetation of the Wequetequock-Pawcatuck tidal-marshes, Connecticut: Ecological Monographs, vol. 12, No. 2, pp. 144-172.

Murray, J.W. (1971) Living foraminiferids of tidal marshes: a review: Journal of Foraminiferal Research, vol. 1, No. 4, pp. 153-161.

O'Neil, T. (1949) The muskrat in the Louisiana coastal marshes: New Orleans, Louisiana Dept. Wild Life and Fisheries, 152 pp.

Palmisano, A.W. (1970) Plant community-soil relationship in Louisiana coastal marshes: Unpubl. PhD dissertation, Louisiana State University, Baton Rouge, LA. 98 pp.

Palmisano, A.W. and R.H. Chabreck (1972) The relationship of plant communities and soils of the Louisiana coastal marshes: Proc. La. Assoc. of Agronomists, vol 13, pp. 72-101.

Parker, F.L. and W.D. Athearn (1959) Ecology of marsh foraminifera in Popponesset Bay, Massachusetts: Journal of Paleontology, vol. 33, No. 2, pp. 333-343.

Penfound, W.T. (1952) Southern swamps and marshes: The Botanical Review, vol. 18, No. 6, pp. 413-446.

Penfound, W.T. and E.S. Hathaway (1938) Plant communities in the marshlands of southeastern Louisiana: Ecological Monographs, vol. 8, No. 1, pp. 3-55.

Phleger, F.B. (1955) Ecology of foraminifera in southeastern Mississippi delta area: Bulletin of the American Association of Petroleum Geologists, vol 39, No. 5, pp. 712-752.

Phleger, F.B. (1970) Foraminiferal populations and marine marsh processes: Limnology and Oceanography, vol. 15, pp. 522-534.

Phleger, F.B. and W.R. Walton (1950) Ecology of marsh and bay Foraminifera, Barnstable, Massachusetts: Am. Jour. Science, vol. 248, pp. 274-294.

Pohl, R.W. (1975) How to Know: The Grasses: Wm. C. Brown Co., Dubuque, Iowa.

Poirrier, M.A. (1969) Louisiana fresh water sponge taxonomy, ecology, and distribution: Unpubl. PhD dissertation, Louisiana State University, Baton Rouge, LA.

Price, M.V. (1980) On the significance of test form in benthic salt-marsh foraminifera: Journal of Foraminiferal Research, vol. 10, No. 2, pp. 129-135.

Radford, A.E., H.E. Ahles, and C.R. Bell (1968) Manual of the Vascular Flora of the Carolinas: The University of North Carolina Press, Chapel Hill, 1183 pp.

Russell, R.J. (1942) Flotant: Geogr. Rev., vol. 32, pp. 74-98.

Russell, R.K. (1970) Geochemistry and halmyrolysis of clay minerals, Rio Ameca, Mexico: Geochimica et Cosmochimica Acta, vol. 34, pp. 893-907.

Schofield, W.B. and H. Robinson (1960) Late-glacial and postglacial plant macrofossils from Gillis Lake, Richmond County, Nova Scotia: American Journal of Science, vol. 258, pp. 518-523.

Scott, D.B. (1976) Brackish-water foraminifera from southern California and description of *Polysaccammina ipohalina* n. gen., n. sp.: Journal of Foraminiferal Research, vol. 6, No. 4, pp. 312-321.

Shiflet, T.N. (1963) Major ecological factors controlling plant communities in Louisiana marshes: J. Range Management, vol. 16, No. 5, pp. 231-235.

Sholkovitz, E.R. (1976) Flocculation of dissolved organic and inorganic matter during the mixing of river water and seawater: Geochimica et Cosmochimica Acta, vol. 40, pp. 831-845.

Simpson and Gilbert (1973) Gemmulation, gemmule hatching, and sexual reproduction in fresh water sponges: Trans. Amer. Micros. Soc., vol. 92, pp. 422-433.

Simpson and Fell (1974) Dormancy among the Porifera: Gemmule formation and germination in fresh-water and marine sponges: Trans. Amer. Micros. Soc., vol 93, pp. 544-577.

Sokal and Sneath (1963) Principles of Numerical Taxonomy, Freeman Press, San Fransisco

Spackman, W. (1958) The maceral concept and the study of modern environments as a means of understanding the nature of coal: Trans. N.Y. Acad. Sci. Ser II, vol. 20(5), pp. 411-423.

Spackman, W. and R. Thompson (1964) A coal constituent classification designed to evolve as knowledge of coal composition evolves: 5th International Congress on Stratigraphy and Geology of the Carboniferous, Paris, 1963, Compte Rendu, vol. 1, pp. 239-254.

Spackman, W., C.P. Dolsen, and W. Riegel (1966) Phytogenic organic sediments and sedimentary environments in the Everglades-mangrove complex; Part I, Evidence of a transgressing sea and its effects on environments of the Shark River area of southwestern Florida: Paleontographica, pt. B, pp. 135-152.

Spears, D.A. (1973) Relationship between exchangable cations and paleosalinity: Geochimica et Cosmochimica Acta, vol. 37, pp. 77-85.

Stach, E., M.-Th. Mackowsky, M. Teichmuller, G.H. Taylor, D. Chandra, and R. Teichmuller (1975) Stach's Textbook of Coal Petrology (2nd ed.). Gerbruder Borntraeger, Berlin, Stuttgart, 428 pp.

Staplin, F.L. (1969) Sedimentary organic matter, organic metamorphism, and oil and gas occurence: Bulletin of Canadian Petroleum Geology, vol. 17, No. 1, pp. 47-66.

Steineck, P.L. and J. Bergstein (1979) Foraminifera from Hommocks salt-marsh, Larchmont Harbor, New York: Journal of Foraminiferal Research, vol. 9, No. 2, pp. 147-158.

Swanson, V.E., A.H. Love, and I.C. Frost (1972) Geochemistry and diagenesis of tidal-marsh sediments, nothwestern Gulf of Mexico: Geological Survey Bulletin 1360, pp. 1-83.

Tan, K.H. (1975) The catalytic decomposition of clay minerals by complex reaction with humic and fulvic acid: Soil Science, vol. 120, No. 3, pp.188-194.

Teichmuller, M. (1971) Anwendung kohlenpetrographischer methoden bei der erdol-und erd gas prorospektion: Erdol u. Khole, vol. 24, pp. 69-76.

Timofeev, P.P. and L.I. Bogoliobova (1975) Relation of changes of organic and clay substances in deposits of the Recent peat accumulation areas: In B. Alpern ed. Petrographie de la Matiere Organique des Sediments, Relations avec la Paleotemperature et la Potentiel Petrolier, Editions Du Centre National De La Recherche Scientifique, Paris, France, pp. 153-172.

Waksman, S.A. (1930) Chemical composition of peat and the role of microorganisms in its formation: Am. Jour. Sci., 5th series, vol. 19, pp. 32-54.

Waldron, R.P. (1963) A seasonal ecological study of foraminifera from Timbalier Bay, Louisiana: Contribution No. 63-3, Coastal Studies Institute, Louisiana State University, Baton Rouge, LA.

Watts, W.A. and T.C. Winter (1966) Plant macrofossils from Kirchner Marsh, Minnesota - A paleoecological study: G.S.A. Bull., vol. 77, pp. 1339-1360.

Watts, W.A. and R.C. Bight (1968) Pollen, sed, and mollusk analyis of a sediment core from Pickerel Lake, northeastern South Dakota: G.S.A. Bull., vol. 79, pp. 855-876.

Welder, F.A. (1959) Processes of deltaic sedimentation in the lower Mississippi River: Technical Report 12, Coastal Studies Institute, Louisiana State University, Baton Rouge, LA., 90 pp.

Wrenn, J.H. and S.W. Beckman (1981a) Maceral and total organic carbon analyses of DVDP drill core 11: In L.D. McGinnis ed., Dry Valley Drilling Project, American Geophysical Union, Antarctic Research Series, vol. 33, pp. 391-402.

Wrenn, J.H. and S.W. Beckman (1981b) Maceral and total organic carbon analyses of the Ross Ice Shelf project site J-9 cores: Antarctic Journal of the United States, vol. XVI, No. 5, pp. 69-71.

Wrenn, J.H. and S.W. Beckman (1982) Maceral, total organic carbon, and palynological analyses of Ross Ice Shelf project site J-9 cores: Science, vol. 216, pp. 187-189.

APPENDIX I. SEED ATLAS

INTRODUCTION TO SEED ATLAS

The purpose of this appendix is to document the seed and other recognizable plant and animal fossils encountered in this study. Each fossil description contains a short summary of available environmental distributions, a morphological description, and a photograph. This appendix contains descriptions of 36 seed taxa, one plant organ, two unknown fossils, and fish scales.

A quantitative distribution graph of marsh type is presented for some taxa. These distributions are derived from data in Chabreck (1972) (see Table 10 and Table 13). The data is in bar graph format, plotted as the percent contribution of the taxa to each marsh type (saline, brackish, intermediate, and fresh). Semi-quantitative and qualitative distribution data are derived from other sources (Penfound and Hathaway, 1938; Penfound, 1952; O'Neill, 1949; Russell, 1942; Radford et al., 1968; Fassett, 1969; and Hotchkiss, 1970). When little or no distribution data were available, paleoenvironment was determined by association with other seed taxa in the cores.

Morphological descriptions of the seeds are provided, including important identification clues. The morphological descriptions consist of size, shape (outline and

cross-section), color, external features and processes, and, when applicable, state of preservation.

A photograph of each fossil is presented as an aid in identification.

LISTING OF PLANT TAXA

Acnida alabamenesis Standl.

Carex sp. L.

Centella asiatica (L.) Urban

Cladium jamaicense Crantz

Cyperus erythrorhizos Muhl.

Cyperus odoratus L.

Distichlis spicata (L.) Greene

Dulichium sp. L.C. Rich.

Eichornia crassipes (Mart.) Solms

Eleocharis obtusa (Willd.) Schultes

Eleocharis parvula (Roemer & Schultes) Link ex Buff. and Fingerh.

Eleocharis sp. R. Br.

Fimbristylis castanae (Michx.) Vahl

Hydrocotyle umbellata L.

Hypericum sp. L.

Juncus roemerianus Scheele

Jussiaea sp. L.

Lythrum lineare L.

Myriophyllum spicatum L.

Najas quadalupensis (Spreng.) Magnus

Panicum agrostoides Spreng.

Panicum hemitomon Schultes

Panicum sp. L.

Panicum virgatum L.

Polygonum sp. A L.

Polygonum sp. B L.

Potamogeton pusillus L.

Ptilimnium nutalli (DC.) Britt.

Sagittaria falcata Pursh

Sagittaria latifolia Willd.

Sagittaria platyphylla (engelm.) J.G. Sm.

Scirpus californicus (C.A. Mey.) Steud.

Scirpus robustus Pursh

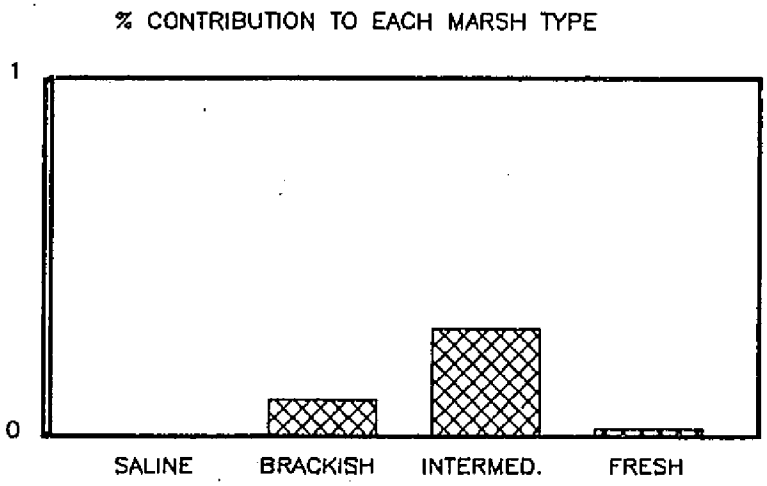
Spartina alterniflora Loisel.

Utricularia sp. L.

Zannichellia palustris L.

Zizaniopsis miliacea (Michx.) Doell & Aschers.

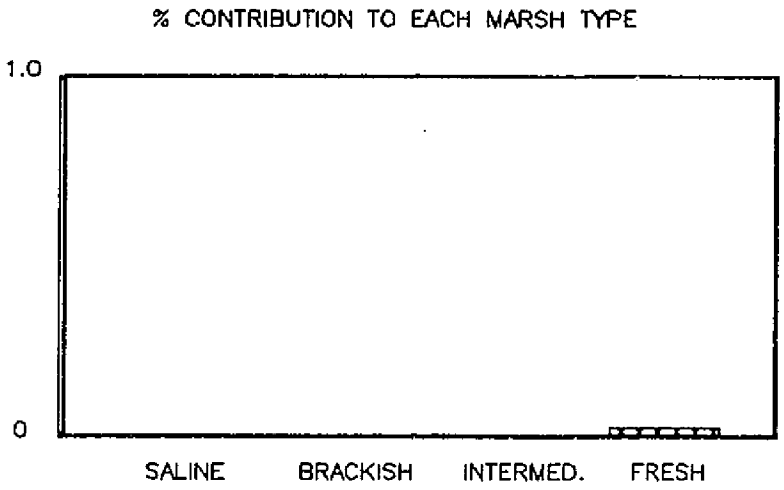
Acnida alabamensis



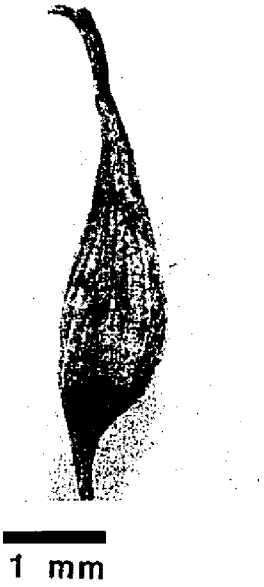
DESCRIPTION: The seeds of Acnida alabemensis are dark, lustrous, hard circular to obovoid grains enclosed within a transparent and membranous sheath. The hard grain is between 1 to 1.5 mm long. Most seeds recovered from the peats were very well preserved and still enclosed in the fragile sheath.

1 mm

Carex sp.



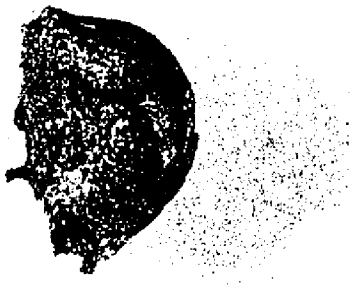
DESCRIPTION: The seeds from the genus Carex are recognizable by the presence of a perigynium (sac) covering the actual seed. The species encountered in this study exhibited a longitudinally ribbed perigynium with a prominent notched beak at one end. The perigynium is approximately 4 to 5 mm long.



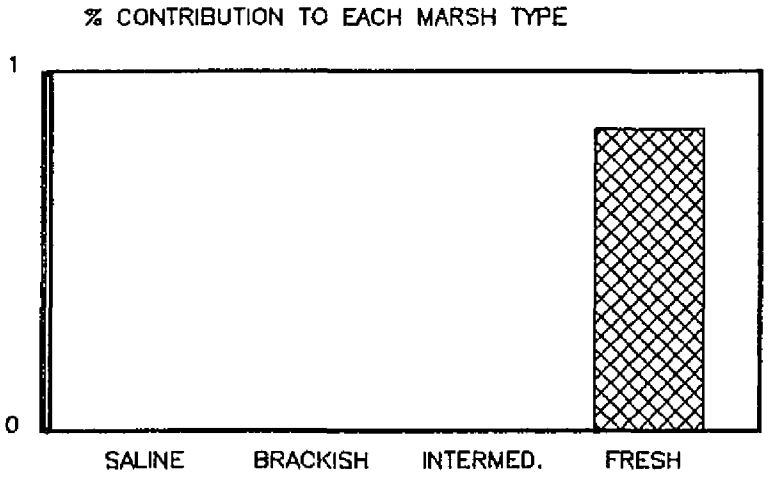
Centella asiatica

DISTRIBUTION: No distributional data for this species available for the Louisiana Coastal region. However, the species Centella erecta occurs in the fresh and intermediate marshes.

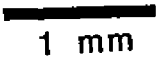
DESCRIPTION: The seed is flat, with one edge straight and the other edge rounded (semi-circular outline). The seed is approximately 4 mm long and contains 2 or 3 branched vein-like ribs. [This seed is very similar in appearance to Hydrocotyle umbellata. Distinguishing features of Centella asiatica are its larger size and surficial rib pattern.]



Cladium jamaicense



DESCRIPTION: The seed remnants encountered from the buried peats consisted of the inner hard, round, black ball. The ball is pointed at one pole with a crown at the other pole. Three equiangular furrows run from the pointed pole to the crown. The seed is approximately 2 mm long.



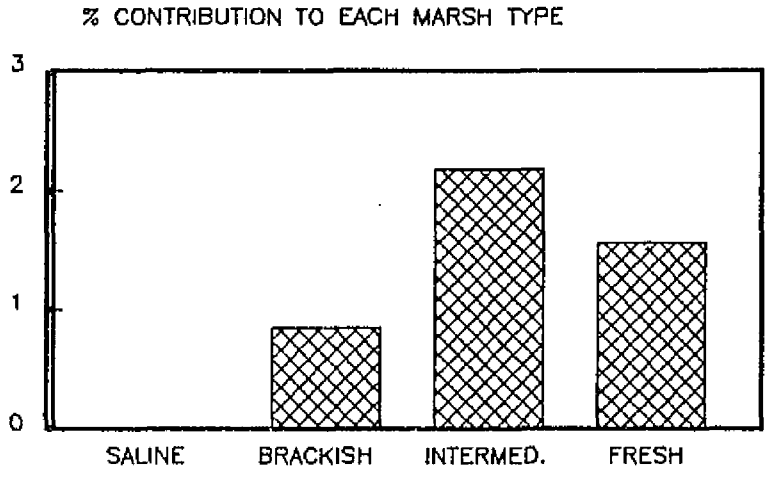
Cyperus erythrorhizos

DISTRIBUTION: This species of the genus Cyperus was not reported in published distributional studies of coastal Louisiana vegetation. In the present study, the seeds of this species were rarely encountered over short intervals in cores SM08 and SWLA3. The data from this study indicate an association between Cyperus erythrorhizos and Cyperus odoratus. On the basis of this association, Cyperus erythrorhizos can be considered an intermediate to fresh marsh species.

DESCRIPTION: Nutlets are very small (.6 to .8 mm long), plano-convex and broadly ellipsoid to ovoid. The nutlets are tan to dark brown, and somewhat lustrous.

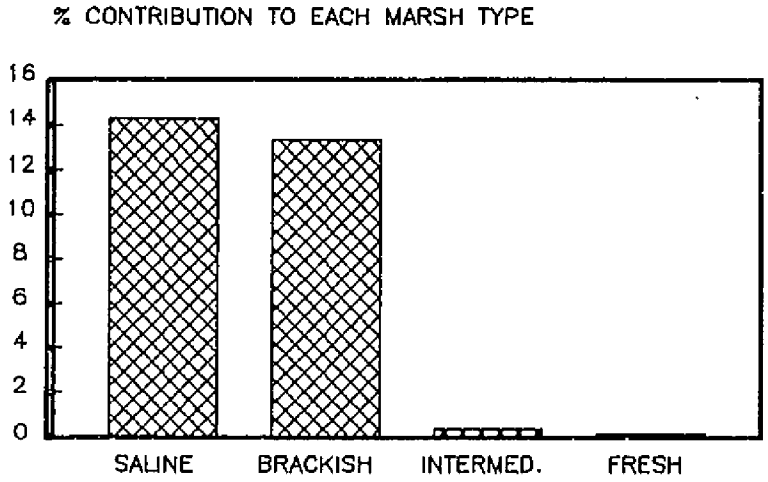
1 mm

Cyperus odoratus

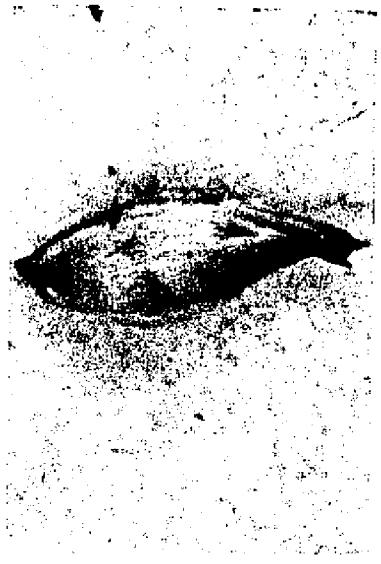


DESCRIPTION: Nutlets trigonous-elongate, approximately 1.5 mm long, brown. The characteristic feature of Cyperus odoratus is the checkerowed, cellular papillae on the surface of the nutlet. Some Cyperus odoratus seeds were partially contained in a soft, light brown fleshy coating.

Distichlis spicata



DESCRIPTION: Grains of Distichlis spicata are light brown, approximately 2 mm long, obliquely ovoid. The characteristic identification clue is a bi-horned structure (rachilla) at one end. Specimens recovered were well preserved.



Dulichium sp.

DISTRIBUTION: No distributional data available for this species of the genus Dulichium. In this study, the vertical distribution of the taxa was limited to the basal portion of core SWLA3, in association with Panicum sp., Polygonum sp. B, and Cyperus odoratus. On the basis of this association, the taxa can be assigned to a fresh marsh habitat.

DESCRIPTION: The seeds are light tan in color, linear-ellipsoid in outline, lens shaped in cross section, and approximately 3 mm long. The characteristic feature of this seed is the long style beak.

Eichornia crassipes

DISTRIBUTION Eichornis crassipes was introduced to Louisiana about 1890. This free floating plant is predominately fresh water and can dominate bayous and lakes. Because of its exotic origin, the seeds serve as a time marker in paleobotanical studies. The appearance of Eichornia crassipes in core SWLA4 at 50 cms indicates rapid sedimentation rates (.5 cm/yr) in the upper portion of this core.

DESCRIPTION: Seeds are minute, ca 1 mm long, oblong to cylindrical in outline. The seeds are covered by coarse cellular reticulations. One end of the seed is somewhat pointed, while the other end is truncated.

1 mm

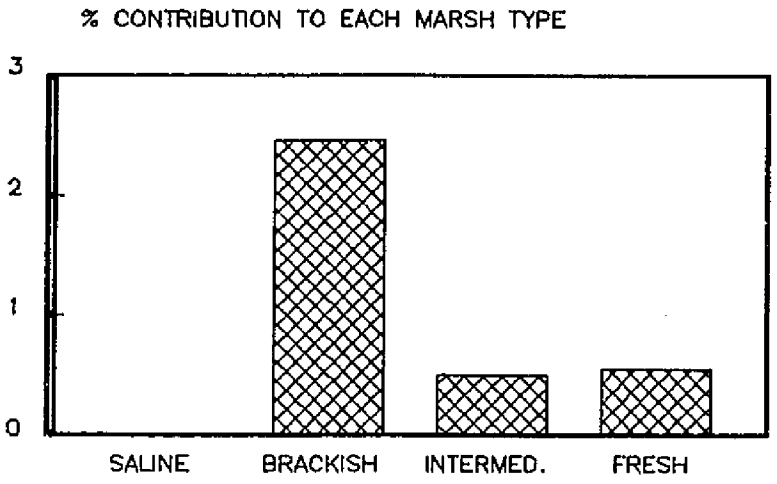
Eleocharis obtusa

DISTRIBUTION: No quantitative data is available for this species of the genus Eleocharis. The general distribution for species of this genus is from fresh to brackish marshes. In the present study, E. obtusa seeds were recovered in low abundances from a short interval in core SW1A3. This interval contained a high species richness of fresh to intermediate marsh vegetation.

DESCRIPTION: The seeds are yellowish to brown, obovoid-biconvex, and lustrous. The seeds are approximately 1 mm long, with a flattened tubercule and 6 barbed bristles. [the specimens encountered in the buried peats did not contain bristles, probably due to depositional processes]

1 mm

Eleocharis parvula



DESCRIPTION: Nutlets are light yellow, trigonous to tetragonous and obovoid. The nutlets are approximately 1 mm long and .7 mm wide. The tubercule is continous with the body. Four to six barbed bristles extend from the base of the nutlet to the top of the tubercule.

1 mm

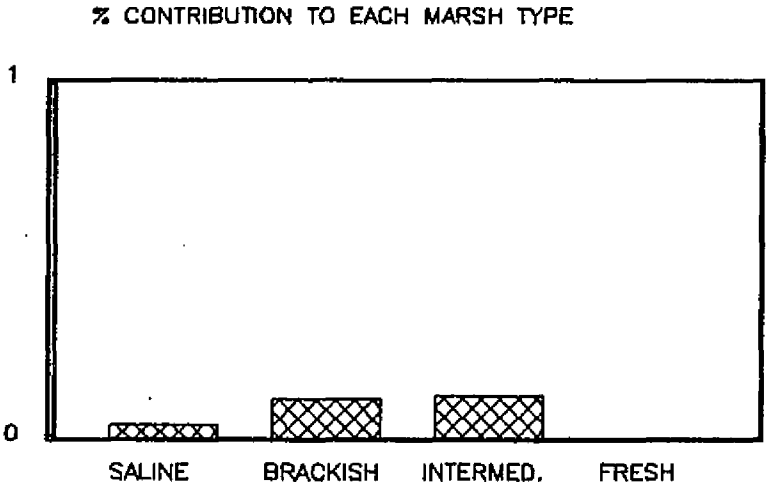
Eleocharis sp.

DISTRIBUTION: The inability to taxonomically identify these seeds to the species level disallows a quantiatative environmental distribution. However, Chabreck and Condrey (1979) report that species of Eleocharis are found from fresh to brackish marshes. The data from this study indicate an association between Eleocharis sp. seeds and seeds of other intermediate to brackish marsh species.

DESCRIPTION: This species of the genus Eleocharis is obovoid-quadrangular, with a prominent tubercule, and 6 barbed bristles. The seed is approximately 2 mm long.

1 mm

Fimbristylis castanea



DESCRIPTION: Nutlets are lenticular, brownish-black in color, approximately 1.5 mm long and 1 mm wide. The prominent identifying feature is the cancellate surface with obvious longitudinal lines.

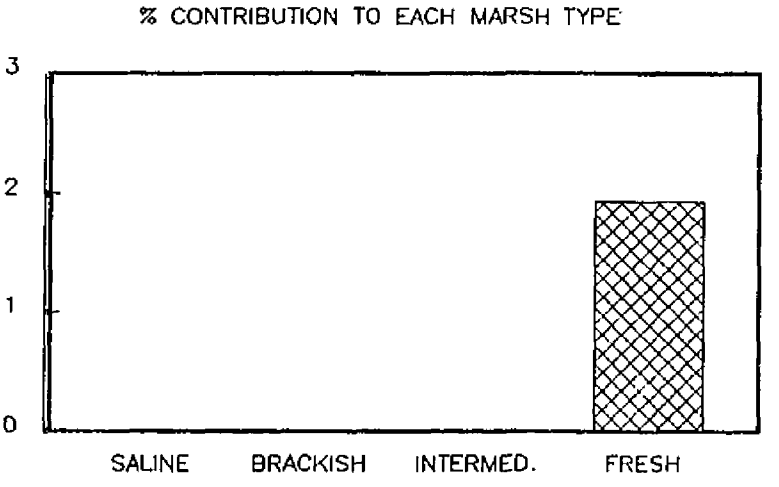
Fish Scales

DISTRIBUTION: Fish scales were recovered, and tabulated, with the seed analyses. They were encountered exclusively in the limnic paleo-environment of core SWLA4, in association with the seeds of aquatic plants.

DESCRIPTION: These Teleost scales are of the ctenoid type, ie exhibiting finger-like or comb-like protuberances. The scales are large (4 to 5 mm long), semi-circular, and partially transparent. They appear orange to red under a binocular microscope in reflected light.

1 mm

Hydrocotyle umbellata



DESCRIPTION: Seeds are flat, one side rounded, the other side straight. Seeds are approximately 3 mm long. An identifying feature is the straight ribs on the surface of the seed.

Hypericum sp.

DISTRIBUTION: The species Hypericum virginicum is restricted to, and is a minor component of, the Louisisna coastal fresh marsh. The exact distribution of the species of Hypericum encountered in this study is unknown.

DESCRIPTION: Seeds are black to dark brown, cylindrical and approximately 2 mm long. These seeds have a slightly reticulated surface.

1 mm

Incertae sedis A

DISTRIBUTION: Origin unknown. These fossils were recovered, in great abundance, from a narrow interval of core SWLA4 (95 to 103 cms). This interval also contains a very high abundance of Ptilimnium nutalli seeds. This brief zone also coincides with a rapid change in salinity.

DESCRIPTION: The fossil is 3 to 4 mm long, semi-circular in outline, and flattened on both sides in cross section. A prominent notch occurs on one end of the straight edge. The fossil is orange to brown, and consists of a spongy material. No internal features are present.

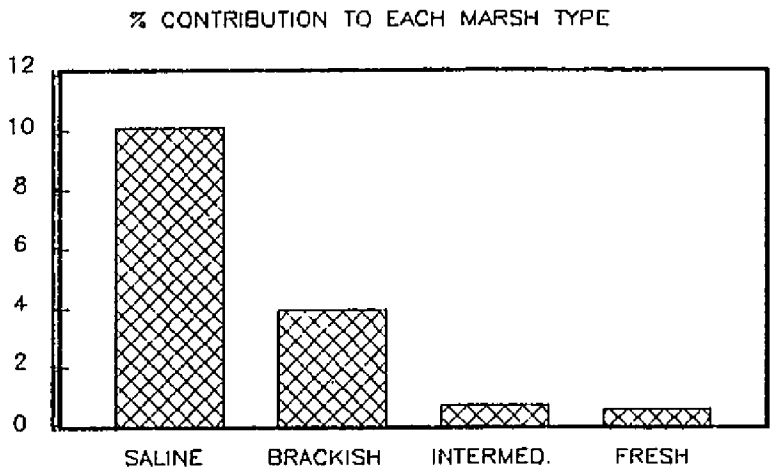
1 mm

Incertae sedis B

DISTRIBUTION: Origin unknown. These fossils were recovered from the fresh to intermediate marsh paleo-environments of core SM08.

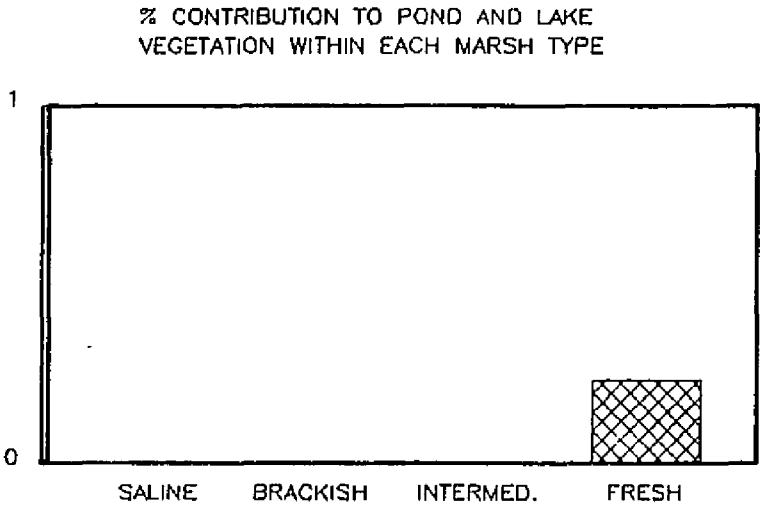
DESCRIPTION: This fossil is elliptical-ovate in outline, pointed at one end, with a prominent stalk at the apex of the other end. The fossil is approximately 3 mm long. Distinguishing features are the numerous spiny protuberances and the surficial longitudinal striations.

Juncus roemerianus



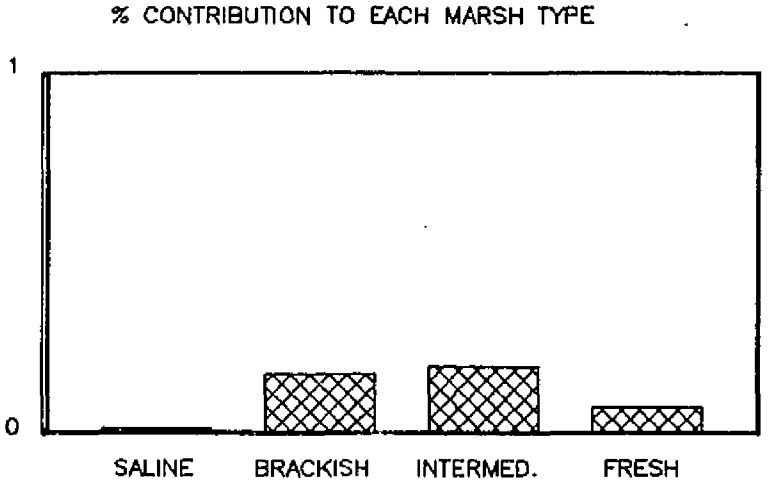
DESCRIPTION: Seeds are brown to black, very minute (ca. .5 mm long), and ellipsoid in outline. Seeds are marked with cellular reticulations.

Jussiaea sp.



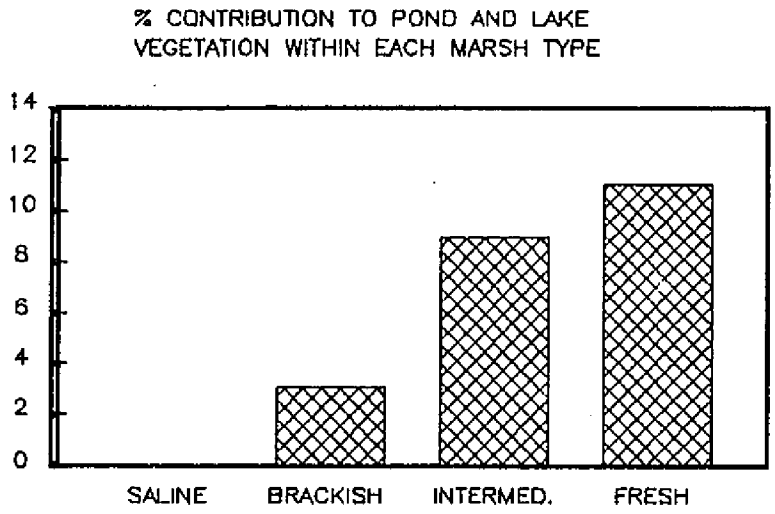
DESCRIPTION: The seeds of Jussiaea sp. are minute, light brown in color, approximately .5 to .7 mm long, and ellipsoid in outline with narrowed ends. A lengthwise dark flange is obvious. Some seeds recovered from the buried peats were enclosed in a heart shaped corky material.

Lythrum lineare



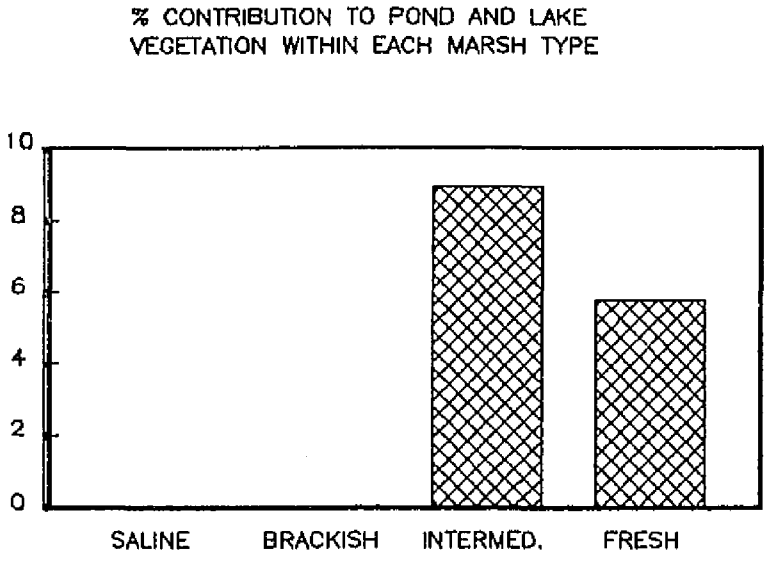
DESCRIPTION: The seeds are minute (approximately .7 mm long), brownish-yellow in color, and linear-elliptical in outline. Very fine cellular reticulations mark the surface.

Myriophyllum spicatum

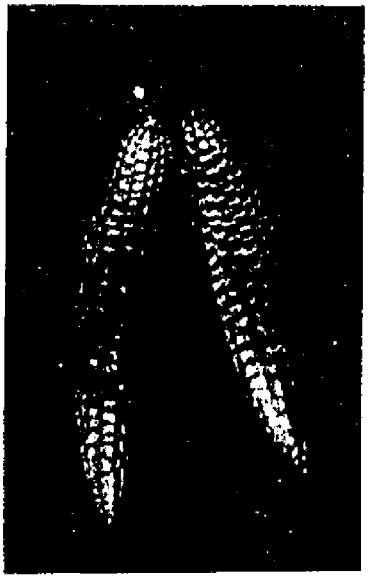


DESCRIPTION: The seeds are oblong rounded-triangular, and approximately 1.5 mm long. Each side of the triangular surface is prominently depressed, and obscurely warty on the rounded surface.

Najas quadalupensis



DESCRIPTION: The seeds are pointed, oval-oblong, and 2 to 3 mm long. The diagnostic features of Najas quadalupensis are the prominent coarse reticulations. The seeds are yellow and appear partially transparent.



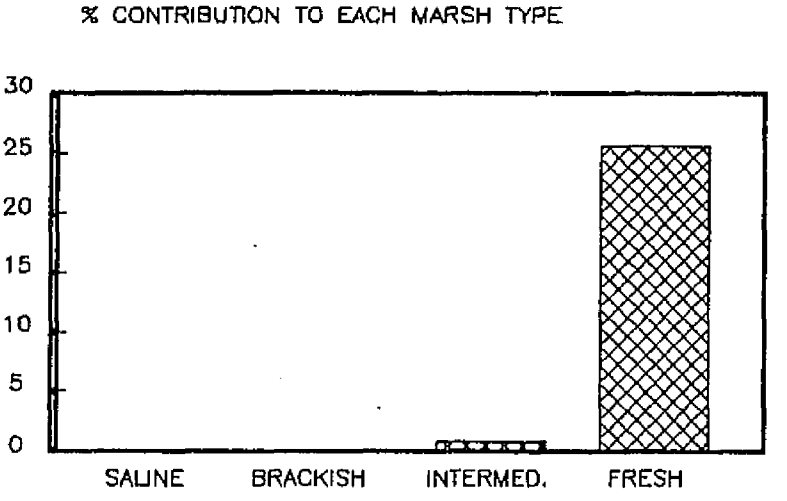
Panicum agrostoides

DISTRIBUTION: No quantiatative data available for this species. Semi-quantiatative distribution data (Penfound and Hathaway 1938) indicate a slightly brackish marsh environment of deposition. In this study, the seeds of this taxa were recovered from a predominately fresh marsh interval in core SWLA3.

DESCRIPTION: The seeds are broadly ovate, 2 mm long, with a round dot evident at the base of the flat side.

1 mm

Panicum hemitomon



DESCRIPTION: Fruit lanceolate (widespread at base and tapering at the apex), approximately 2.5 mm long. The specimens recovered from the buried peats were more severely degraded as compared to the other seeds of the PANICUM genus. Hitchcock (1950) reports the "fruit less rigid than usual in the genus".

1 mm

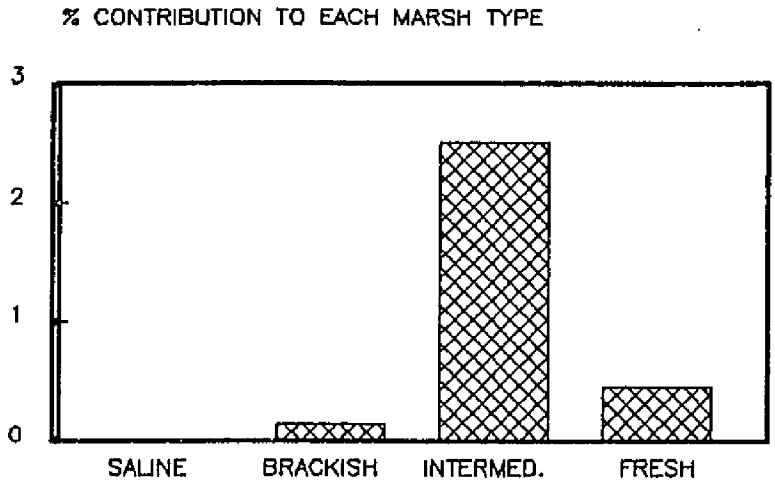
Panicum sp.

DISTRIBUTION: The genus Panicum occurs in intermediate and fresh marshes. The distribution of this seed fossil in the study cores suggest fresh to intermediate marsh habitats.

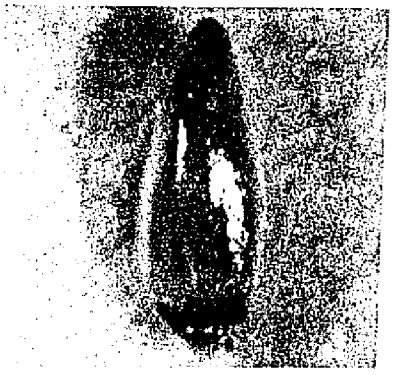
DESCRIPTION: These outer seed coverings from a species of Panicum are 3 to 4 mm long, and ellipsoid in outline. The seed coverings recovered from the sediments were collapsed, lacking structural integrity. The diagnostic features are the prominent longitudinal striations typical of the genus Panicum.

1 mm

Panicum virgatum

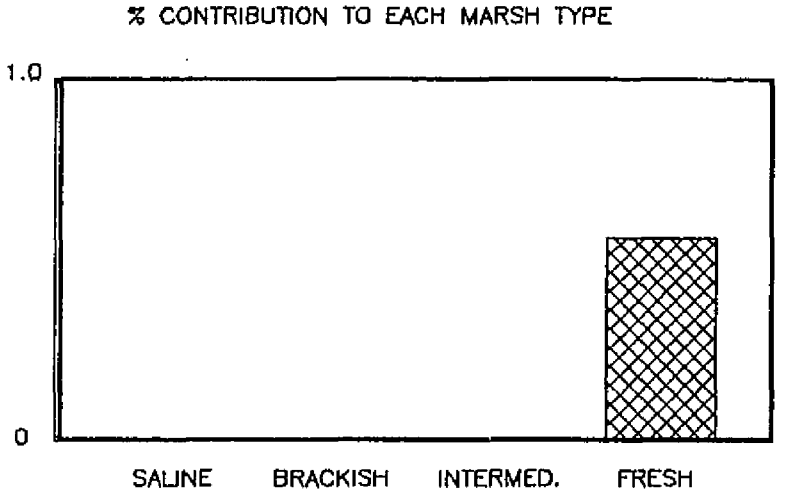


DESCRIPTION: Seeds are narrowly ovate in outline, approximately 3 mm long, light brown with a dark spot at the base of the flat side. The specimens recovered were moderately well preserved.



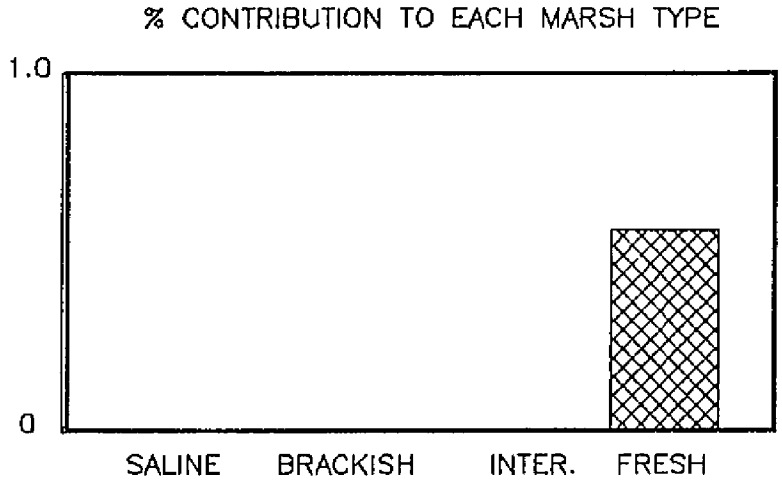
1 mm

Polygonum sp. A

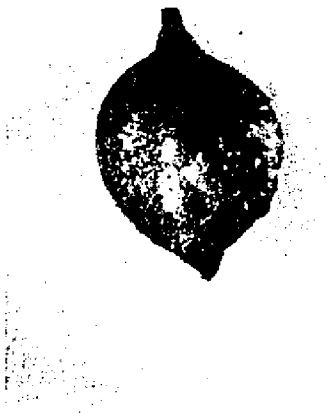


DESCRIPTION: This species of the genus Polygonum contains a hard outer wall (pericarp) which is ovate-triangular, dark brown to black, and 3 mm long. The characteristic features of the pericarp are the numerous pustules and the erect stalk at the apex.

Polygonum sp. B

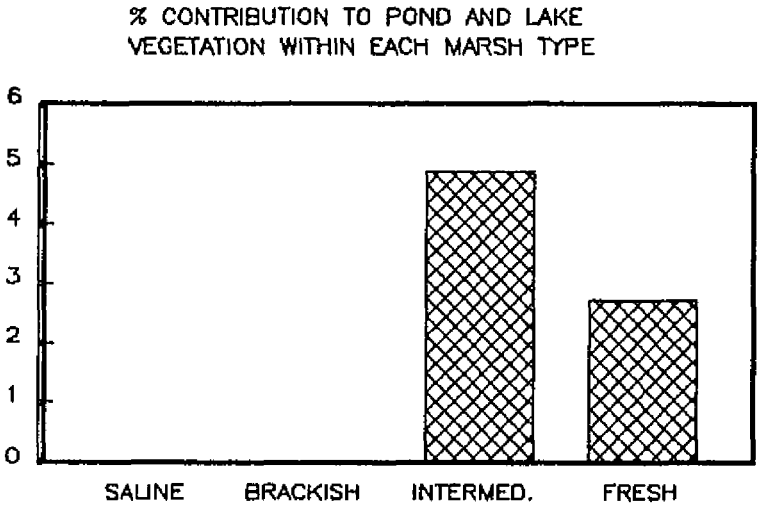


DESCRIPTION: This species of the genus Polygonum is circular to ovate in outline and lens shaped in cross-section. The seed is 3 to 4 mm in its longest dimension, dark brown to black and very hard.

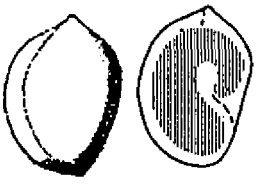


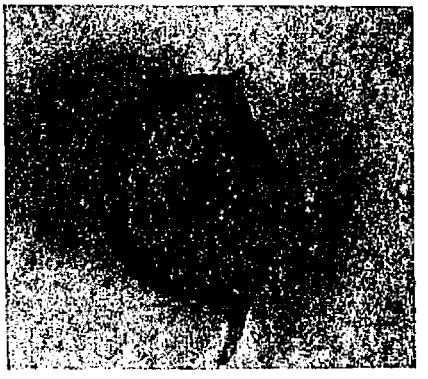
1 mm

Potamogeton pusillus



DESCRIPTION: Seeds of Potamogeton are identified by external, and when applicable, internal features. Externally, the seeds of Potamageton pusillus are earlike, starchy, with a pointed style base, and 2 to 3 mm long. The internal features of Potamogeton pussilus are illustrted below.





1 mm

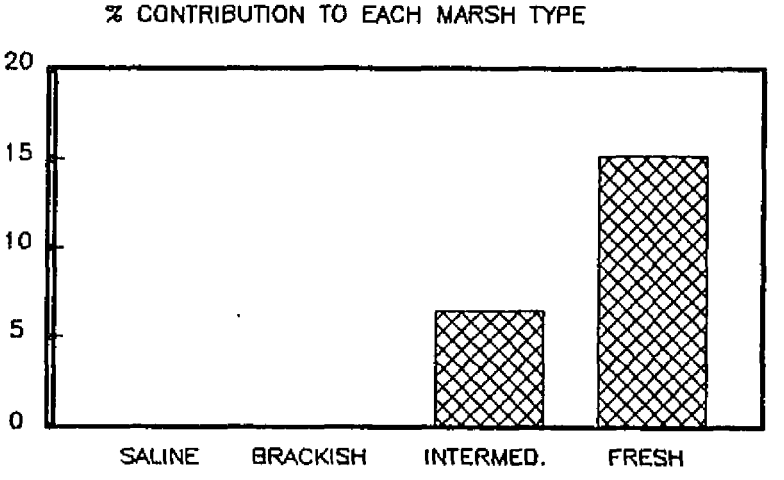
Ptilimnium nutalli

DISTRIBUTION: Neither quantitative nor qualitative distributional data available for the Louisiana marshlands. Its occurence in other states (Radford et al 1968) indicate a fresh water habitat. In this study, the seeds of this species were abundantly recovered from narrow depth zones in all three cores. These zones were coincident with rapid paleosalinity changes.

DESCRIPTION: The seeds are large (2 to 3 mm long), ovoid in outline with a flattened side in cross section. The characteristic fetures are the 6 to 8 prominent lengthwise ribs on the rounded surface, and the starchy dark material between the ribs.

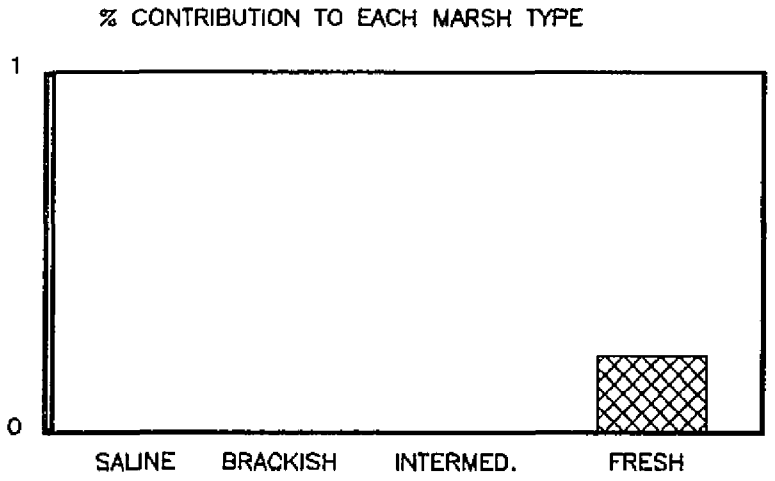
1 mm

Sagittaria falcata

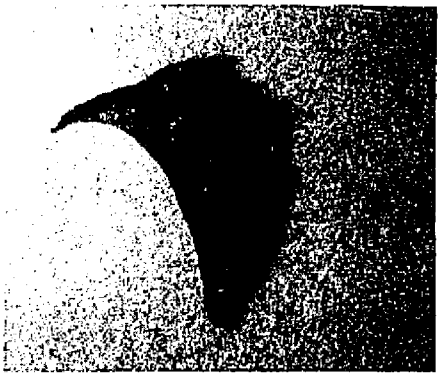


DESCRIPTION: Achenes wingshaped, relatively small for the genus (1.5 to 2 mm long). The beak forms an oblique angle with the body of the achene. The U shaped embryo is obvious.

Sagittaria latifolia

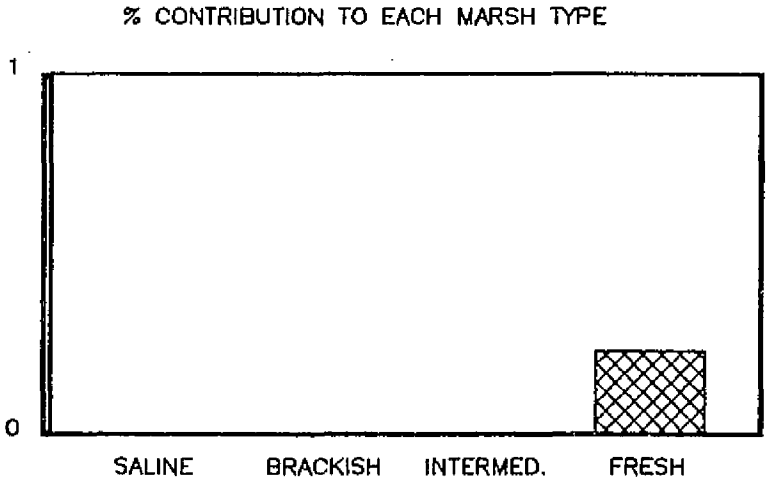


DESCRIPTION: Achenes large, approximately 2.5 to 4 mm long, thin walled and translucent around the margins. The distinguishing feature is the long beak which lies almost perpendicular to the main axis of the achene.



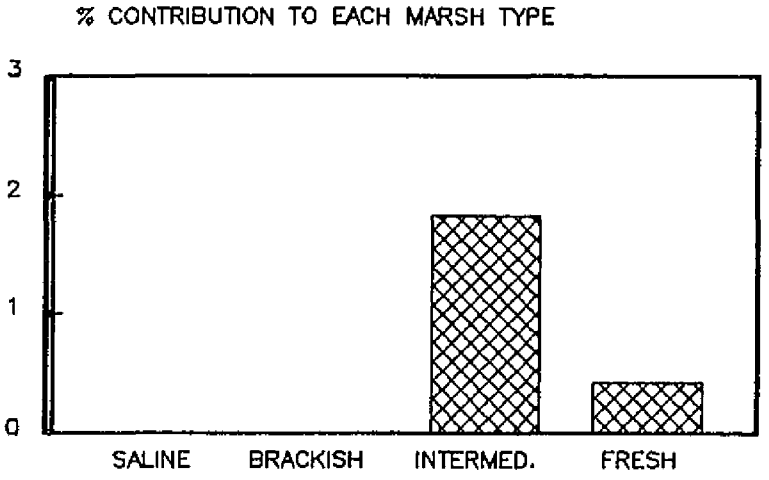
1 mm

Sagittaria platyphylla



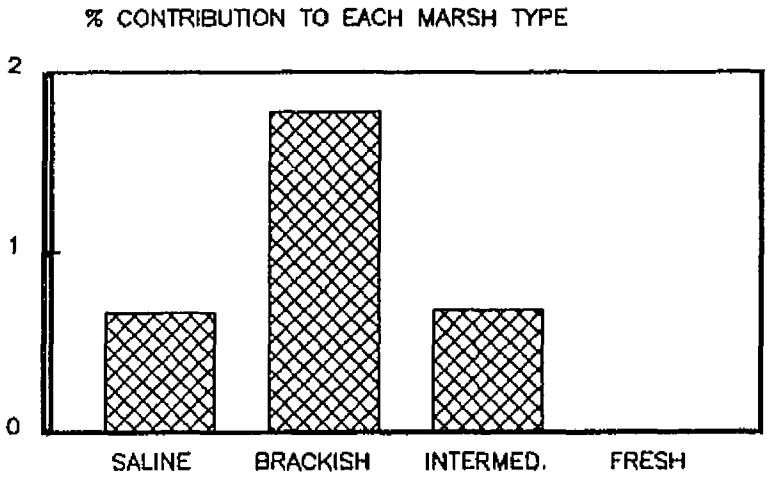
DESCRIPTION: Achenes moderately large (approximately 3 mm long). The distinguishing characteristic of this species is the relatively short beak which extends almost horizontally from the main axis of the achene. [all specimens recovered from the buried sediments were moderately degraded, exhibiting poor morphologic integrity]

Scirpus californicus



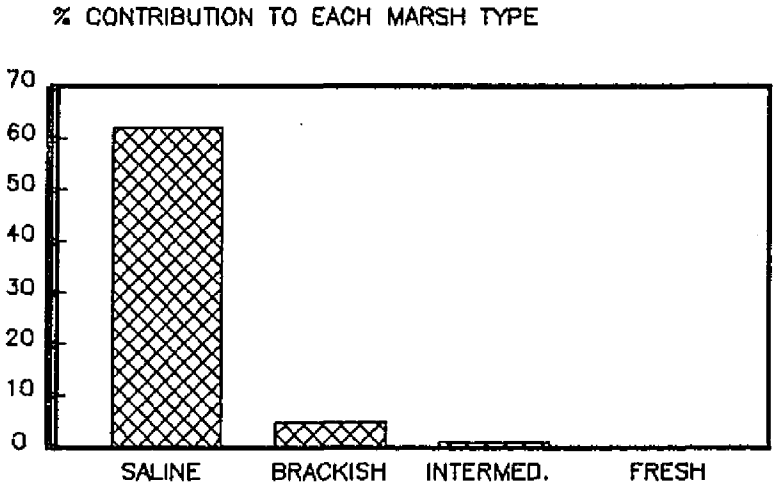
DESCRIPTION: Nutlets are brown, plano-convex in cross section, ellipsoid-obovoid in outline, and 2 mm long. No bristles were observed on any specimens recovered from the buried peats.

Scirpus robustus

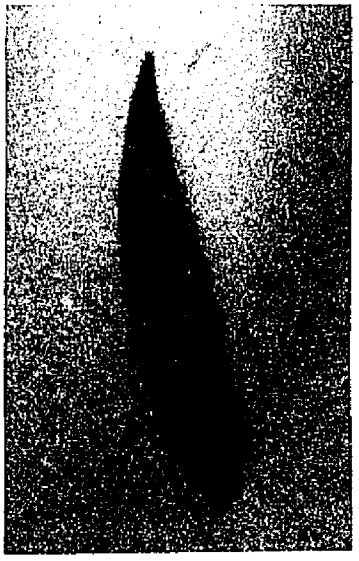


DESCRIPTION: Nutlets are dark brown, with a smooth and lustrous texture. Lenticular in cross section, obovoid in outline. Approximately 3 mm long. [fresh nutlets have 1-4 yellowish bristles extending halfway up the nutlet; no bristles were observed on any nutlet recovered from the buried peats]

Spartina alterniflora



DESCRIPTION: No grains were recovered from any sample. Only portions of the floret were rarely encountered in the surficial sediments of each core. An example of a recovered lemma is presented. Lemma is 9-10 mm lomg, light brown, elongate, concave on one side.



1 mm

Utricularia sp.

DISTRIBUTION: The species Utricularia cornuta occurs in fresh ponds and lakes and reaches maximum abundance in ponds between .01 to 1.0 acres in area. In this study, seeds of Utricularia sp. were abundantly recovered from the lake facies in the basal portion of core SWLA4.

DESCRIPTION: Seeds are flat, rounded, and approximately 3 mm in diameter. The seed is rimmed by a series of protuberances. The central portion of the seed is depressed with an obvious raised knob at the center.

1 mm

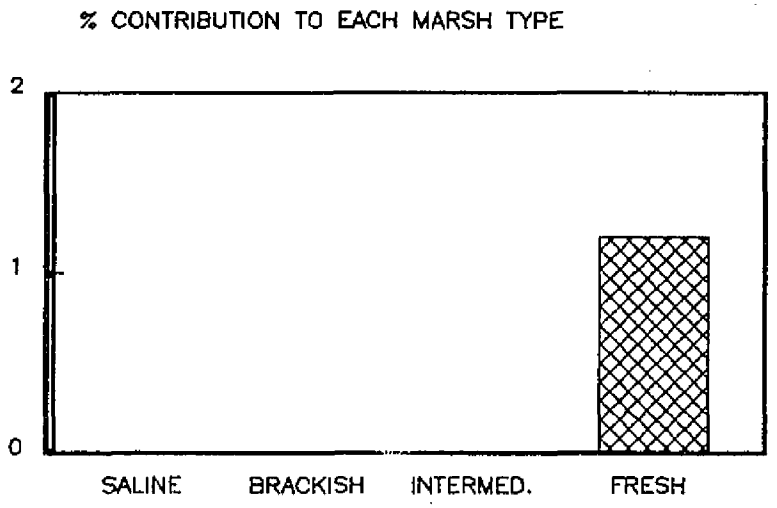
Zannichellia palustris

DISTRIBUTION: Neither quantitative nor qualitative distribution data available for the Louisiana coastal region. This submerged aquatic occurs in waters of pools, ponds, and estuaries. Seeds of Zannichellia palustris were very abundant in the bottom half of core SWLA4 in association with Utricularia sp., Potamageton pusillus, and Najas quadalupensis. Therefore, this species is proposed to be indicative of a generally fresh lake or pond environment.

DESCRIPTION: The actual seed of Zannichellia palustris is brown to olive in color and 2 to 3 mm long. The seed is enveloped in an outer seed cover. The enveloped seed is 4 to 5 mm long, 1 mm wide, cylindric-falcate, with a slightly dentate wing on the body. There is an obvious 1 to 2 mm long style.

1 mm

Zizaniopsis miliacea



DESCRIPTION: Obovate in outline, coriaceous (leathery) to smooth texture, approximately 6 mm long. Obvious style or remnant of style at rounded apex. The structures at each apex are offset.

1 mm

APPENDIX II. FORAMINIFERA ATLAS

INTRODUCTION TO FORAMINIFERA ATLAS

Foraminifera are excellent paleoenvironmental indicators for saline-influenced marsh and bay-lake sediments. Since most marsh taxa are agglutinated, extreme care should be exercised during isolation and identification to avoid destruction of these delicate structures. Drying and abusive sieving should be avoided in favor of wet picking methods.

In this study, 12 taxa were observed, ten agglutinated and two hyaline taxa.

Several morphological criteria were used for identification.

(1) composition of the test - agglutinated vs. hyaline
(2) chamber arrangement - trochospiral, planispiral
(3) shape of sutures including presence of processes
(4) position and type of aperture(s)
(5) size and number of chambers

The following atlas contains descriptions and photographs of taxa encountered in this study. Special notes are made on specific features that help distinguish morphologically similar taxa.

LISTING OF FORAMINIFERA TAXA

Ammoastuata inepta (Cushman and McCulloh) 1939

Ammonia spp. Brunnich 1772

Ammotium salsum (Cushman and Bronimann) 1948

Arenoparella mexicana (Kornfeld) 1931

Elphidium spp. De Montfort 1808

Haplophragmoides sp. Cushman, 1910

Jadammina polystoma Bartenstein and Brand 1938

Milliammina fusca (H.B. Brady) 1870

Recurvoides sp. Earland 1934

Tiphotrocha comprimata (Cushman and Bronimann) 1948

Trochammina inflata (Montagu) 1808

Trochammina marcescens H.B. Brady 1870

Ammoastuata inepta

DESCRIPTION

The test is agglutinated and ovate in outline. The distinguishing feature is the curved, semi-enrolled serial chamber arrangement. The primary aperture is a transverse areal slit on the face of the final chamber. Secondary cribrate apertures are found at the base of the final chamber.

X 300

Ammonia spp.

DESCRIPTION

The species of this genus have a calcareous hyaline test. The test is free, trochospiral (low), and biconvex in shape. Sutures are straight to slightly curved. The umbilical side has several fused pillars. This genus has an interiomarginal aperture.

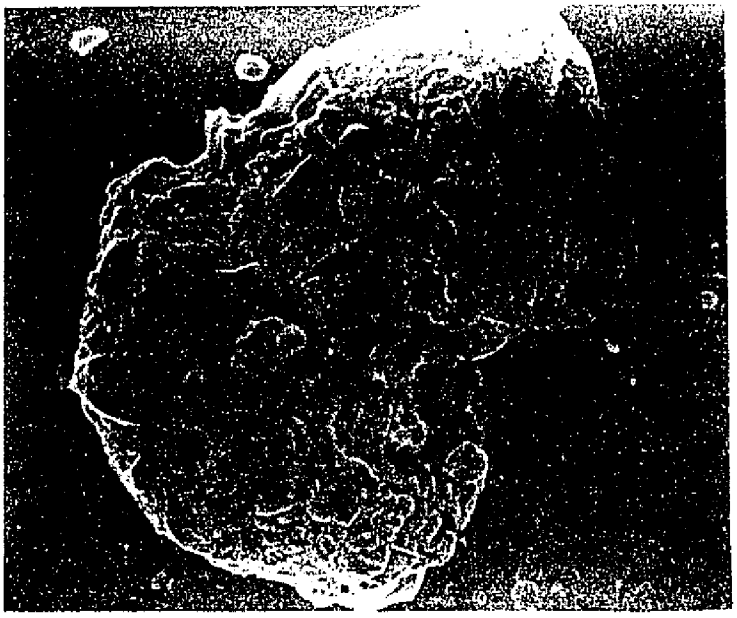
Note: Species of this genus were associated with Elphidium in the marine influenced limnic and marginal limnic paleo-environments.

X 300

Ammotium salsum

DESCRIPTION

The test is free, compressed, and ovate in outline. The agglutinated test is composed of large grains. The chambers are planispirally coiled, evolute, with the final chambers being partially uncoiled. The aperture is simple, rounded, and terminal, and is located on the final chamber.



X 240

Arenoparella mexicana

DESCRIPTION

The test is free, trochospiral, and agglutinated. The sutures are radial to slightly curved. The umbilcal side (see photo) has a closed umbilicus. The distinguishing feature of A. mexicana is the elongate, vertical, slitlike primary aperture on the face of the final chamber. Additional cribate openings may also be present on the face of the final chaamber.

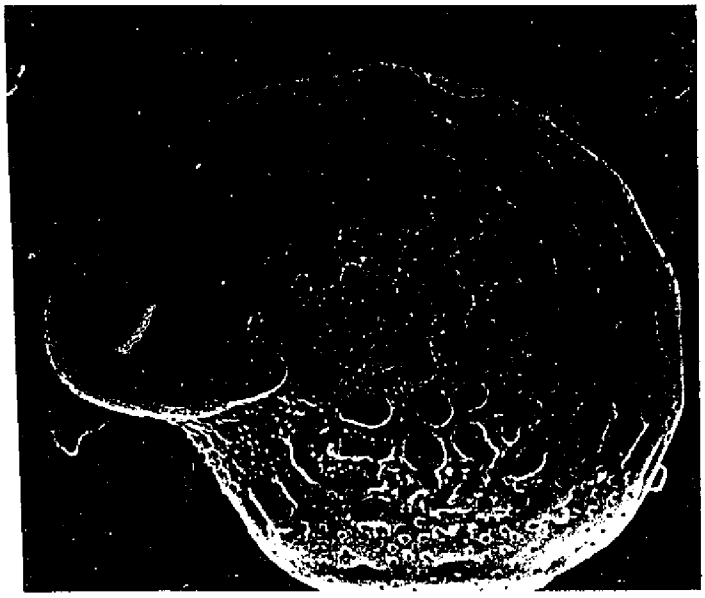
X 300

Elphidium spp.

DESCRIPTION

Species of this genus have a calcareous hyaline test. The test is bilaterally symetrical and involute. Identifying features are the numerous chambers with retral processes (backward pointing extensions of the chamber cavity), and the tubular perforations connecting the chambers. The aperture is a row of pores at the base of the septal face.

Note: This genus was predominately encountered in the brackish to saline lake environments. Reworked fossils were occasionaly encountered from marsh sediments that bordered the limnic environments.



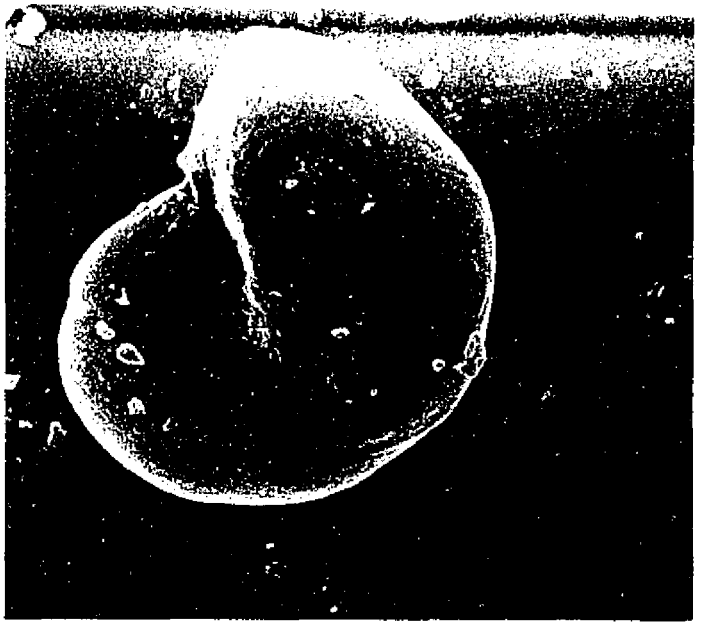
X 240

Haplophragmoides sp.

DESCRIPTION

The test is free, agglutinated, and planispirally coiled. The chambers are involute (overlap). The aperture is an equatorial interiomarginal slit. Haplophragmoides sp. is very broad in edge view.

Note: Haplophragmoides sp. can be distinguished from other agglutinated marsh forams by its non-trochospiral test. The test is planispirally coiled.



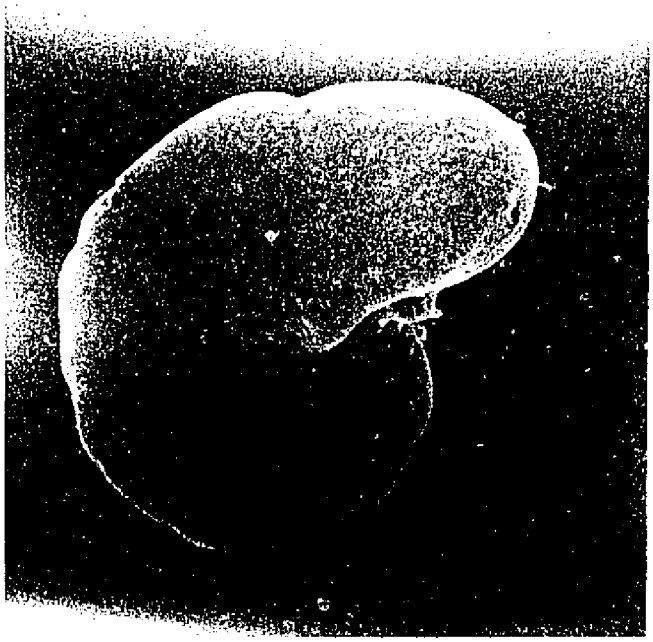
X 300

Jadammina polystoma

DESCRIPTION

The test is agglutinated and trochospiral with a flattened appearance. Sutures are distinct and radial to gently curving. The identifying features are the apertures; the primary one being a low interio-marginal equatorial slit with a supplementary areal aperture on the final chamber face.

NOTE: Jadammina polystoma is very similar in morphology to Trochammina marcescens. The distinguishing features of J. polystoma are the interio-marginal equatorial aperture and the secondary areal aperture.



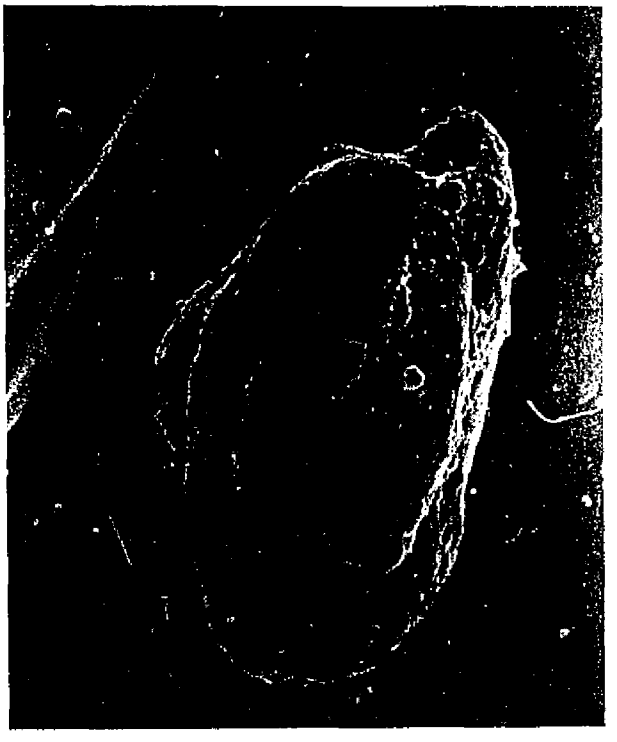
X 200

Milliammina fusca

DESCRIPTION

The tests are free and siliceous. The identifying feature of this foram is the quiqueloculine chamber arrangement. The aperture is round and located at the apex of the final chamber.

X 300

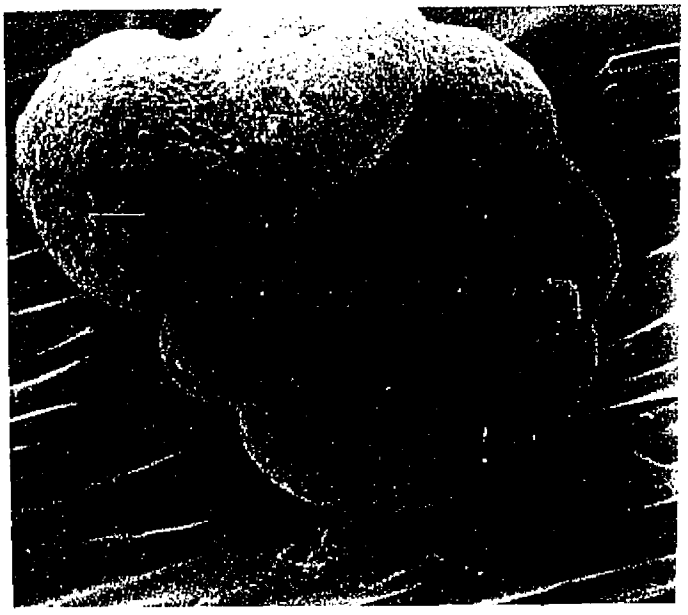


Recurvoides sp.

DESCRIPTION

The test is free, agglutinated, with a streptospiral coiling pattern. In edge view, the chambers occupy different planes, often abruptly changing coiling direction. The distinguishing features are the globular and highly rounded chambers. The aperture is a small areal opening on the final chamber (not easily visible in most specimens encountered).

Note: The great abundance and dominance of Recurvoides sp. in a portion of core SM08 suggests that the distribution of this foraminifera may be controlled by anomolous environmental conditions. Recurvoides sp. was not encountered in any great numbers in the other two study cores.



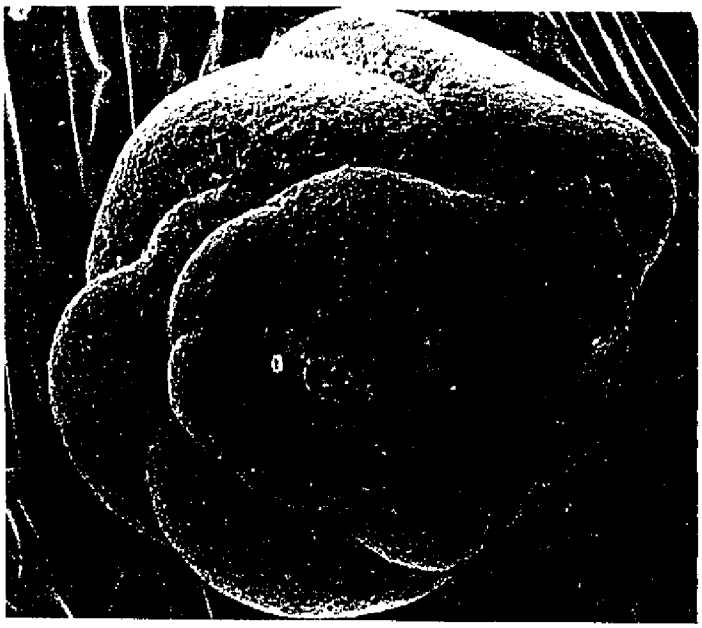
X 180

Tiphotrocha comprimata

DESCRIPTION

The test is free, trochospiral, and agglutinated. Tiphotrocha comprimata is easily distinguishable by the numerous chambers arranged in several whorls. The chambers rapidly increase in size as added, later chambers being crescentrically shaped. The umbilical side is excavated with a small open umbilicus. The sutures are slightly curved on the spiral side and strongly sinuate on the umbilical side. The aperture is interiomarginal extraumbilical- umbilical.

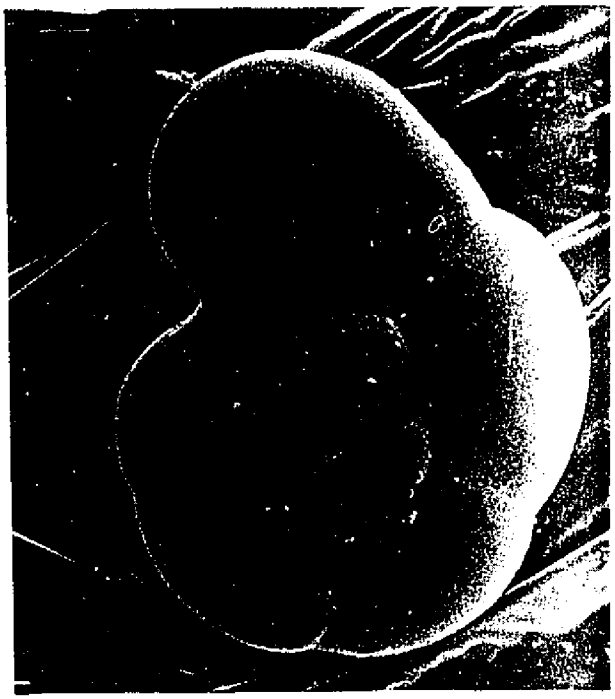
X 240



Trochammina inflata

DESCRIPTION

The test is free, agglutinated, amd trochospiral. The distinguishing feature of T. inflata are the large, globular chambers with rounded outlines. Sutures are well defined and straight to slightly arched. The aperture is a low interiomarginal extraumbilical-umbilical arch.



X 180

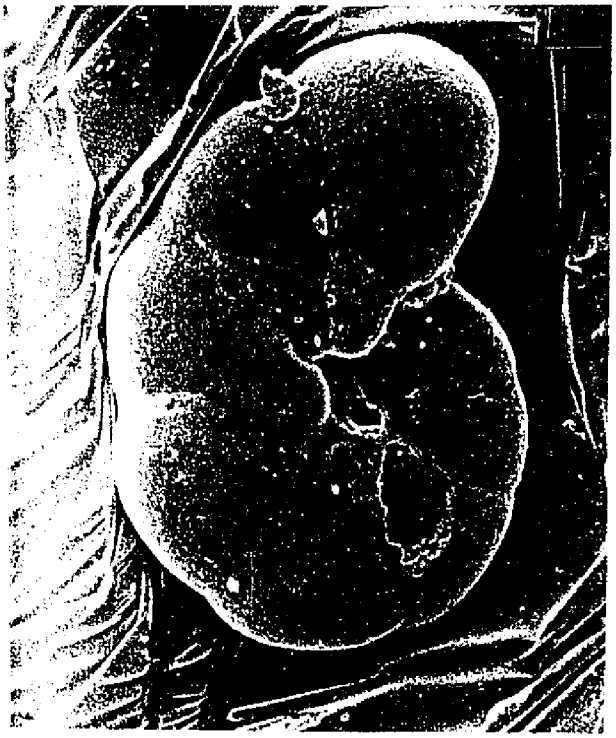
Trochammina marcescens

DESCRIPTION

Test is free, trochospiral, and agglutinated. The sutures are slightly curved to radial. The chambers are slightly globular (although not as globular as in Trochammina inflata). The aperture is an interiomarginal extraumbilical-umbilical slit.

Note 1: Trochammina marcescens is similar in appearance to Jadammina polystoma. T. marcescens is distinguishable by its more rounded and globular chambers, and the interiomarginal extraumbilcal-umbilical aperture.

Note 2: Pseudo-chitonous forms of T. marcescens were recovered from the slightly marine (intermediate marsh) sections of the cores. These pseudo-chitonous forams consist of an organic walled, translucent, orange-brown test with little or no agglutination. The pseudo-chitonous linings shrink and deform rapidly after removal from water.



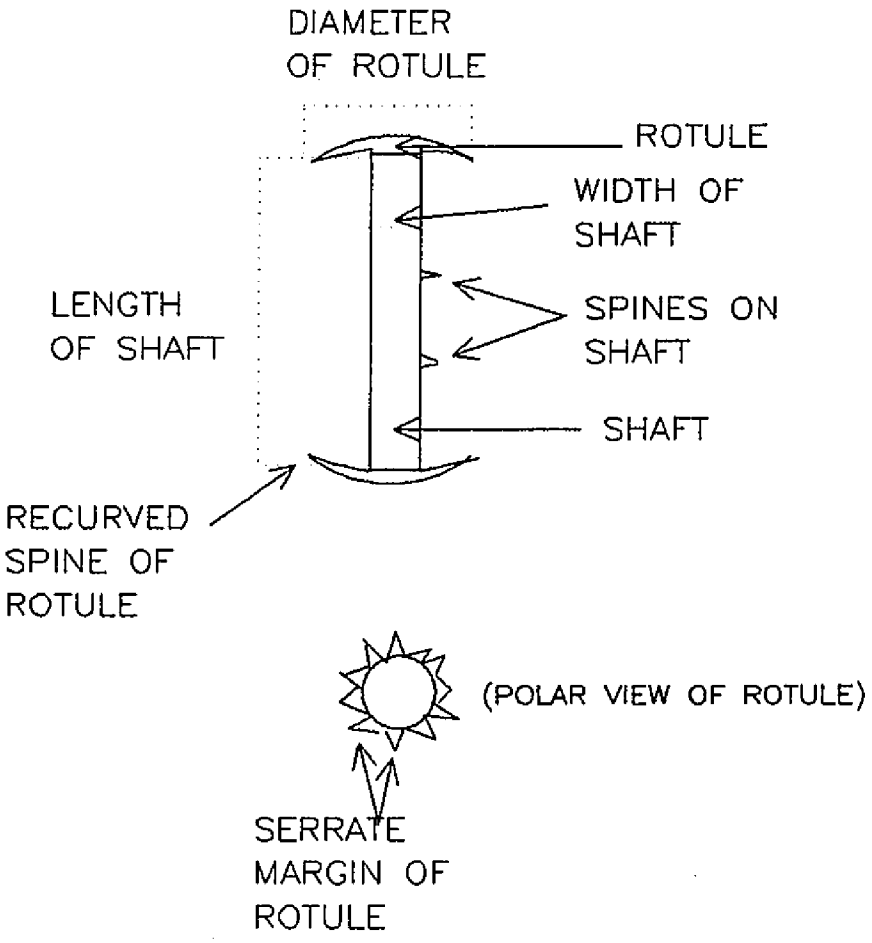
X 200

APPENDIX III. GEMMULE ATLAS

TAXONOMIC IDENTIFICATION OF GEMMULES

Gemmules were identified in this study based on gemmosclere morphology. As discussed in the methods section, the gemmoscleres were isolated by nitric acid digestion of the whole gemmule followed by microscopic examination in transmitted light.

A hypothetical gemmosclere is presented to illustrate the morphological features.



The morphologic features used to taxonomically identify the gemmoscleres are:

(1) size - length of shaft, width of shaft, diameter of rotules (if present)

(2) presence or absence of rotules

(3) morphology of rotules

(4) morphology of shaft

(5) morphology of processes and spines on shaft and/or rotules

The following section includes descriptions and photomicrographs of the gemmoscleres for each freshwater sponge species encountered in this study.

LISTING OF SPONGE TAXA

Anheteromeyenia arygrosperma (Potts) 1880

Anheteromeyenia ryderi (Potts) 1882

Dosilia radiospiculata (Mills) 1888

Ephydatia fluviatalis (Linnaeus) 1759

Heteromeyenia baileyi (Bowerbank) 1863

Radiospongillia crateriformis (Potts) 1882

Spongillia lacustris (Linnaeus) 1759

Anheteromeyenia argyrosperma

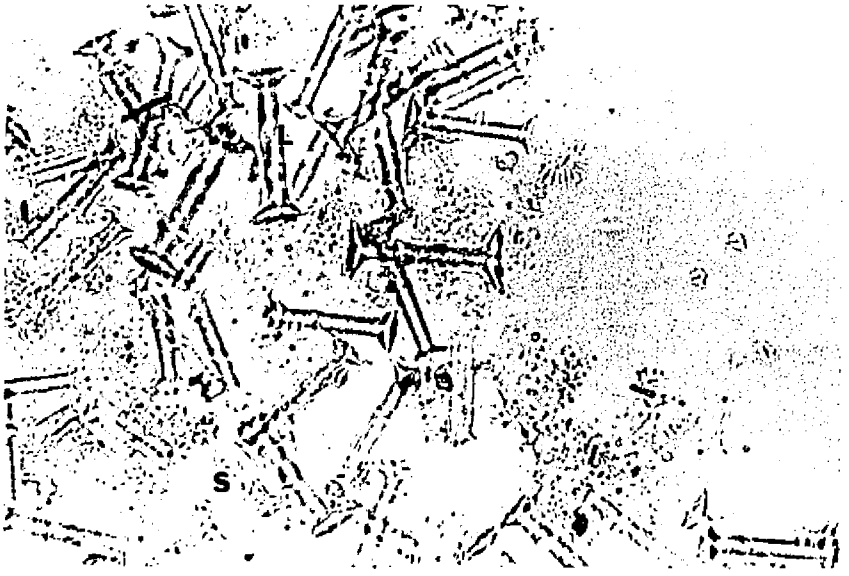
Gemmosclere Morphology

Birotulate gemmosclere with wide shaft and indistinct rotules. Length of shaft is approximately 125 u and contains numerous large spines. Width of shaft is approximately 15 u. The indistinct rotules consist of several irregular spines.

Anheteromeyenia ryderi

Gemmosclere Morphology

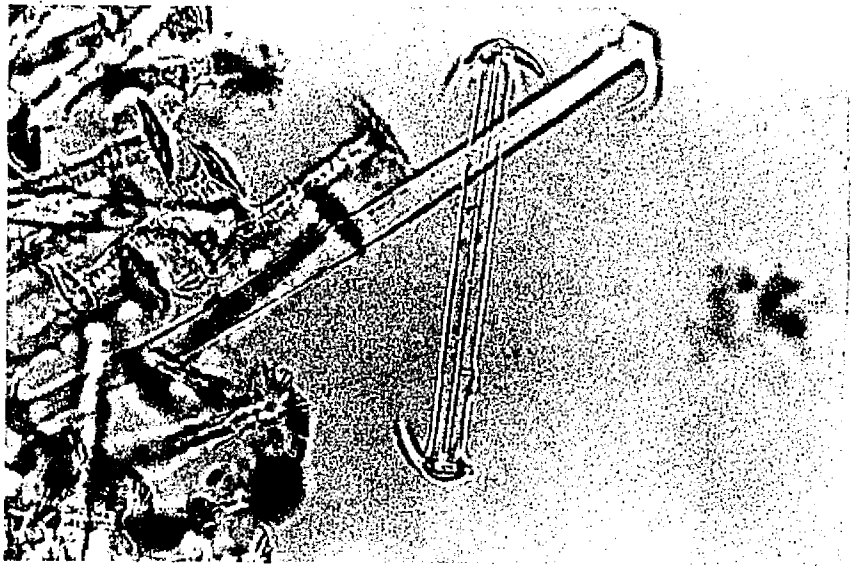
Two classes of birotulates present. Short gemmoscleres (labeled S in photo) are 26 to 46 u long. Large gemmoscleres (labeled L in photo) are 50 to 70 u long. The shafts of both size classes contain numerous small spines.

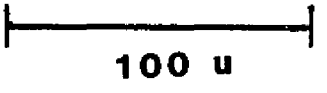


Dosilia radiospiculata

Gemmosclere Morphology

Very large birotulate gemmoscleres. The rotules consist of three or four strongly recurved spines. The length of the shaft varies between 120 to 230 u. The width of the shaft varies from 16 to 20 u.

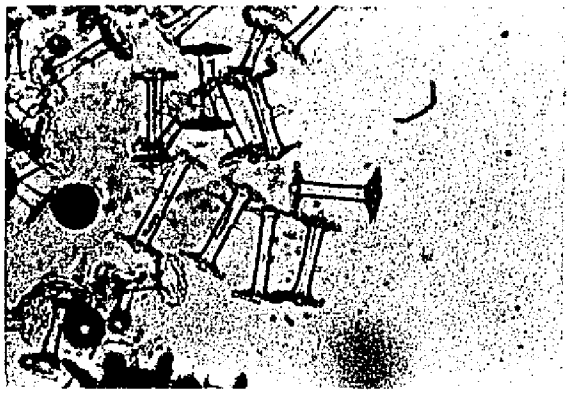




Ephydatia fluviatalis

Gemmosclere Morphology

Birotulates of one class with rotules of equal diameter. Length of shaft is 26 to 30 u and the diameter of the rotules between 18 and 21 u. Polar view of rotules reveals a serrated or toothlike appearance on the margins. The shaft is usually smooth, however, under adverse condtions spines can occur. [Spined gemmoscleres were observed from the slightly saline influenced samples in this study.]

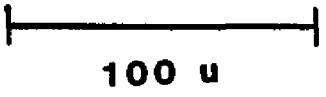


60 u

Heteromeyenia baileyi

Gemmosclere Morphology

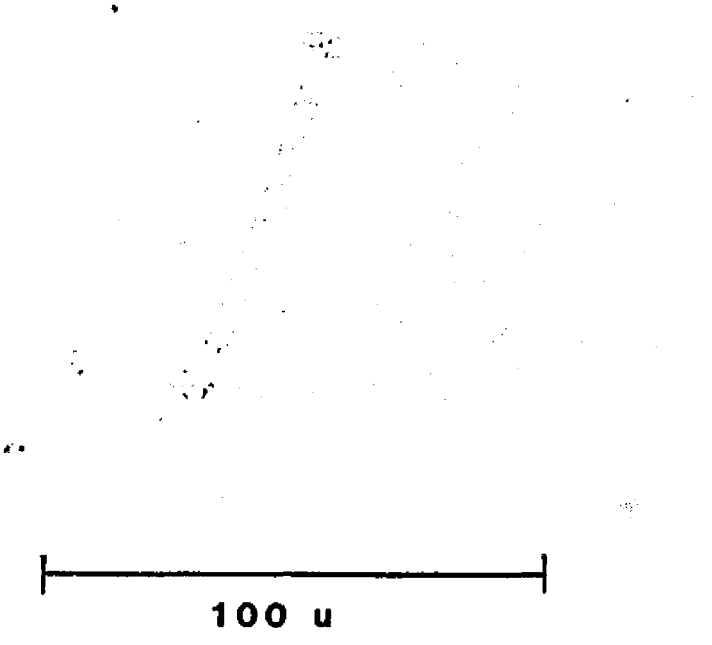
Birotulate gemmoscleres. Rotules of equal size with recurved spines. The shaft contains numerous small, short spines. Length of gemmoscleres are between 100 to 120 u. The width of rotules are approximately 30 u. The width of the shaft is between 6 to 10 u.



Radiospongillia crateriformis

Gemmosclere Morphology

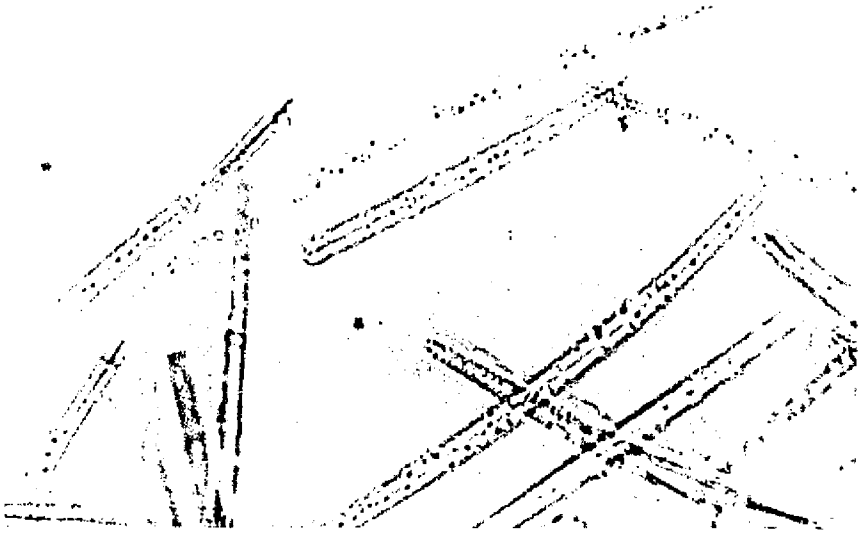
Birotulate gemmosclere with small rotules consisting of a few recurved spines. Length of gemmosclere is between 50 to 70 u. Width of gemmule shaft is approximately 5 u. The shaft contains some spines.



Spongillia lacustris

Gemmosclere Morphology

Rotules are absent. Gemmoscleres are slightly curved with numerous small spines on the shaft. Length of gemmoscleres vary between 50 and 150 u. The width of the gemmosclere at the widest dimension is approximately 5 u.



100 u

APPENDIX IV. SEED DATA

APPENDIX IV SEEDS CORE SWLA4

Depth Interval cm		*Spartina alterniflora*	*Juncus roemerianus*	*Distichlis spicata*	*Lythrum lineare*	*Fimbristylis castanea*	*Eleocharis parvula*	*Scirpus robustus*	*Cyperus odoratus*	*Acnida alabamensis*	*Ptilimnium nuttalii*	*Eleocharis sp.*	*Eleocharis obtusa*	*Polygonum sp. A*	*Panicum virgatum*
0.0	7.6	3	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6	15.2	3	0	1	2	0	0	0	0	0	0	0	0	0	0
15.2	22.9	0	0	1	2	0	0	0	3	0	0	0	0	0	0
22.9	30.5	0	0	1	2	0	0	0	4	0	0	0	0	0	0
30.5	38.1	0	0	2	3	0	0	0	3	2	0	0	0	0	0
38.1	45.7	0	0	1	2	0	0	0	2	2	0	0	0	0	0
47.0	54.6	0	0	1	2	0	0	0	2	2	0	0	0	0	0
54.6	62.2	0	0	1	0	0	0	0	0	2	0	0	0	0	0
62.2	69.9	0	0	2	3	0	0	0	3	0	0	2	0	0	0
69.9	77.5	0	0	3	1	0	1	0	4	0	1	0	0	0	1
77.5	85.1	0	0	0	0	0	0	0	3	0	0	0	0	0	0
85.1	92.7	0	0	0	1	0	0	0	3	0	1	0	0	0	0
96.5	105.4	0	0	0	0	0	0	0	1	0	6	0	0	0	0
105.4	113.0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
113.0	120.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120.7	128.3	0	0	0	0	0	0	0	3	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SWLA4 (contd.)

Depth Interval cm		*Spartina alterniflora*	*Juncus roemerianus*	*Distichlis spicata*	*Lythrum lineare*	*Fimbristylis castanea*	*Eleocharis parvula*	*Scirpus robustus*	*Cyperus odoratus*	*Acnida alabamensis*	*Ptilimnium nutalii*	*Eleocharis sp.*	*Eleocharis obtusa*	*Polygonum sp. A*	*Panicum virgatum*
128.3	135.9	0	0	0	0	0	0	0	2	0	0	0	0	0	0
135.9	143.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
143.5	151.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151.1	158.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
158.8	166.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
166.4	174.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
174.0	184.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
184.2	191.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
191.8	199.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
199.4	203.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
203.2	210.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
210.8	218.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
218.4	226.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
226.1	233.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
233.7	241.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SWLA4 (contd.)

Depth Interval cm		Myriophyllum spicatum	Cladium jamaicense	Scirpus californicus	Jussiaea sp.	Najas quadalupensis	Sagittaria falcata	Potamageton pusillus	Centella asiatica	Carex sp.	Panicum hemitomon	Hypericum sp.	Zizaniopsis miliacea	Sagittaria falcata	Polygonum sp. B
0.0	7.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.2	22.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.9	30.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30.5	38.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38.1	45.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47.0	54.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54.6	62.2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
62.2	69.9	0	1	0	0	0	0	0	0	0	0	0	0	0	0
69.9	77.5	0	0	0	0	0	3	0	0	0	0	0	0	0	0
77.5	85.1	0	0	0	2	0	1	0	0	0	3	0	0	0	0
85.1	92.7	0	0	0	1	0	1	0	0	0	3	0	0	0	0
96.5	105.4	0	4	0	0	0	0	0	0	0	0	0	0	0	0
105.4	113.0	0	0	0	3	0	0	1	0	2	3	0	0	0	0
113.0	120.7	0	0	0	0	1	0	1	0	4	1	0	0	1	2
120.7	128.3	0	0	0	1	0	1	0	0	3	1	0	0	0	1

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SWLA4 (contd.)

Depth Interval cm		Myriophyllum spicatum	Cladium jamaicense	Scirpus californicus	Jussiaea sp.	Najas quadalupensis	Sagittaria falcata	Potamogeton pusilius	Centella asiatica	Carex sp.	Panicum hemitomon	Hypericum sp.	Zizaniopsis miliacea	Sagittaria falcata	Polygonum sp. B
128.3	135.9	0	0	0	0	2	0	1	0	2	1	0	0	3	1
135.9	143.5	0	0	0	0	1	0	1	0	4	1	0	0	4	0
143.5	151.1	0	0	0	0	2	0	1	0	5	1	0	0	5	1
151.1	158.8	0	0	0	0	3	0	1	0	3	0	0	0	0	0
158.8	166.4	0	0	0	0	2	0	3	0	0	0	0	0	0	0
166.4	174.0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
174.0	184.2	0	0	0	0	4	0	0	0	0	0	0	0	0	0
184.2	191.8	0	0	0	0	4	0	0	0	0	0	0	0	0	0
191.8	199.4	0	0	0	0	6	0	4	0	0	0	0	0	0	0
199.4	203.2	0	0	0	0	5	0	4	0	0	0	0	0	0	0
203.2	210.8	0	0	0	0	5	0	4	0	0	0	0	0	0	0
210.8	218.4	0	0	0	0	5	0	5	0	0	0	0	0	0	0
218.4	226.1	0	0	0	0	5	0	3	0	0	0	0	0	0	0
226.1	233.7	0	0	0	0	3	0	3	0	0	0	0	0	0	0
233.7	241.3	0	0	0	0	3	0	2	0	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SWLA4 (contd.)

Depth Interval cm		Utricularia sp.	Zannichellia palustris	Eichornia crassipes	Sagittaria platyphylla	Cyperus erythrorhizos	Hydrocotyle umbellata	Panicum sp.	Dulichium sp.	Panicum agrostoides	Incertae sedis A	Incertae sedis B	fish scales
0.0	7.6	0	0	0	0	0	0	0	0	0	0	0	0
7.6	15.2	0	0	0	0	0	0	0	0	0	0	0	0
15.2	22.9	0	0	0	0	0	0	0	0	0	0	0	0
22.9	30.5	0	0	0	0	0	0	0	0	0	0	0	0
30.5	38.1	0	0	0	0	0	0	0	0	0	0	0	0
38.1	45.7	0	0	0	0	0	0	0	0	0	0	0	0
47.0	54.6	0	0	0	0	0	0	0	0	0	0	0	0
54.6	62.2	0	0	0	0	0	0	0	0	0	0	0	0
62.2	69.9	0	0	0	0	0	0	0	0	0	0	0	0
69.9	77.5	0	0	1	0	3	0	3	0	0	0	0	0
77.5	85.1	0	0	0	0	0	0	3	0	0	0	0	0
85.1	92.7	0	0	0	0	0	0	1	0	0	0	0	0
96.5	105.4	0	0	0	0	0	0	0	0	0	6	0	0
105.4	113.0	0	0	0	0	0	0	2	0	0	0	0	0
113.0	120.7	1	0	0	0	0	0	2	0	0	0	0	0
120.7	128.3	0	0	0	0	0	0	2	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SWLA4 (contd.)

Depth Interval cm		Utricularia sp.	Zannichellia palustris	Eichornia crassipes	Sagittaria platyphylla	Cyperus erythrorhizos	Hydrocotyle umbellata	Panicum sp.	Dulichium sp.	Panicum agrostoides	incertae sedis A	incertae sedis B	fish scales
128.3	135.9	0	0	0	0	0	0	1	0	0	1	0	0
135.9	143.5	0	0	0	0	0	0	1	0	0	0	0	0
143.5	151.1	0	3	0	0	0	0	0	0	0	0	0	0
151.1	158.8	4	3	0	0	0	0	0	0	0	0	0	0
158.8	166.4	4	0	0	0	0	0	0	0	0	0	0	0
166.4	174.0	4	2	0	0	0	0	0	0	0	0	0	0
174.0	184.2	4	5	0	0	0	0	0	0	0	0	0	1
184.2	191.8	4	5	0	0	0	0	0	0	0	0	0	1
191.8	199.4	6	6	0	0	0	0	0	0	0	0	0	1
199.4	203.2	6	6	0	0	0	0	0	0	0	0	0	5
203.2	210.8	6	6	0	0	0	0	0	0	0	0	0	6
210.8	218.4	5	5	0	0	0	0	0	0	0	0	0	5
218.4	226.1	4	4	0	0	0	0	0	0	0	0	0	5
226.1	233.7	3	0	0	0	0	0	0	0	0	0	0	3
233.7	241.3	0	0	0	0	0	0	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SWLA3

Depth Interval cm		*Spartina alterniflora*	*Juncus roemerianus*	*Distichlis spicata*	*Lythrum lineare*	*Fimbristylis castanea*	*Eleocharis parvula*	*Scirpus robustus*	*Cyperus odoratus*	*Acnida alabamensis*	*Ptilimnium nuttalii*	*Eleocharis sp.*	*Eleocharis obtusa*	*Polygonum sp. A*	*Panicum virgatum*
0.0	7.6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6	15.2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15.2	22.9	0	0	0	0	0	0	0	1	0	0	1	0	0	0
22.9	30.5	0	0	0	0	0	0	0	1	0	0	1	0	0	0
30.5	38.1	0	0	1	0	0	0	0	1	0	0	0	0	0	0
38.1	45.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45.7	53.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53.3	61.0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
61.0	68.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68.6	76.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76.2	83.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86.4	94.0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
94.0	101.6	0	0	0	0	0	0	0	0	5	2	0	0	3	0
101.6	104.1	0	0	0	0	0	0	0	0	6	3	0	0	5	0
104.1	111.8	0	0	0	0	0	0	0	4	0	0	0	1	0	0
111.8	119.4	0	0	0	0	0	0	0	0	0	0	2	1	0	0
119.4	127.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
127.0	134.6	0	0	0	0	0	0	0	1	0	0	0	0	0	0
134.6	142.2	0	0	0	0	0	0	0	5	0	0	0	0	0	0
142.2	147.3	0	0	0	0	0	0	0	4	0	0	0	0	0	0
147.3	152.4	0	0	0	0	0	0	0	3	0	0	0	0	0	0
152.4	157.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
157.5	166.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
166.4	175.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SWLA3 (contd.)

Depth Interval cm		Myriophyllum spicatum	Cladium jamaicense	Scirpus californicus	Jussiaea sp.	Najas quadalupensis	Sagittaria falcata	Potamageton pusillus	Centella asiatica	Carex sp.	Panicum hemitomon	Hypericum sp.	Zizaniopsis miliacea	Sagittaria falcata	Polygonum sp. B
0.0	7.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.2	22.9	0	1	0	0	0	0	0	0	0	0	0	0	0	0
22.9	30.5	0	1	0	0	0	0	0	0	0	0	0	0	0	0
30.5	38.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38.1	45.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45.7	53.3	0	1	0	0	0	0	0	0	0	0	0	0	0	0
53.3	61.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61.0	68.6	0	0	0	1	0	0	0	0	0	0	0	0	0	0
68.6	76.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76.2	83.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86.4	94.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94.0	101.6	0	0	0	1	0	0	0	0	0	0	0	0	0	0
101.6	104.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
104.1	111.8	0	2	0	0	0	0	0	0	0	0	0	0	0	0
111.8	119.4	0	0	0	1	0	0	0	0	0	0	3	0	4	0
119.4	127.0	0	0	0	0	0	3	0	0	0	0	1	1	3	0
127.0	134.6	0	0	0	2	0	0	0	0	0	0	1	0	2	0
134.6	142.2	0	0	0	1	0	0	1	0	0	0	0	0	0	5
142.2	147.3	0	0	0	0	0	0	1	0	0	0	0	0	0	4
147.3	152.4	0	0	0	0	0	0	1	0	4	0	0	0	0	0
152.4	157.5	0	0	0	0	0	0	2	0	0	0	0	0	0	0
157.5	166.4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
166.4	175.3	0	0	0	0	0	0	1	0	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SWLA3 (contd.)

Depth Interval cm		Utricularia sp.	Zannichellia palustris	Eichornia crassipes	Sagittaria platyphylla	Cyperus erythrorhizos	Hydrocotyle umbellata	Panicum sp.	Dulichium sp.	Panicum agrostoides	Incertae sedis A	Incertae sedis B	fish scales
0.0	7.6	0	0	0	0	0	0	0	0	0	0	0	0
7.6	15.2	0	0	0	0	0	0	0	0	0	0	0	0
15.2	22.9	0	0	0	0	0	0	0	0	0	0	0	0
22.9	30.5	0	0	0	0	0	0	0	0	0	0	0	0
30.5	38.1	0	0	0	0	0	0	0	0	0	0	0	0
38.1	45.7	0	0	0	0	0	0	0	0	0	0	0	0
45.7	53.3	0	0	0	0	0	0	0	0	0	0	0	0
53.3	61.0	0	0	0	0	0	0	0	0	0	0	0	0
61.0	68.6	0	0	0	0	0	0	0	0	0	0	0	0
68.6	76.2	0	0	0	0	0	0	0	0	0	0	0	0
76.2	83.8	0	0	0	1	0	0	0	0	0	0	0	0
86.4	94.0	0	0	0	0	0	0	3	0	0	0	0	0
94.0	101.6	0	0	0	0	0	0	3	0	0	0	0	0
101.6	104.1	0	0	0	0	0	0	3	0	0	0	0	0
104.1	111.8	0	0	0	0	0	0	4	0	2	0	0	0
111.8	119.4	0	0	0	0	0	0	3	0	0	0	0	0
119.4	127.0	0	0	0	0	0	0	3	3	0	0	0	0
127.0	134.6	0	0	0	0	0	0	3	1	0	0	0	0
134.6	142.2	0	0	0	0	0	0	2	0	0	0	0	0
142.2	147.3	0	0	0	0	0	0	0	3	0	0	0	0
147.3	152.4	0	0	0	0	0	0	0	0	0	0	0	0
152.4	157.5	0	0	0	0	0	0	0	0	0	0	0	0
157.5	166.4	0	0	0	0	0	0	0	0	0	0	0	0
166.4	175.3	0	0	0	0	0	0	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SM08

Depth Interval cm		*Spartina alterniflora*	*Juncus roemerianus*	*Distichlis spicata*	*Lythrum lineare*	*Fimbristylis castanea*	*Eleocharis parvula*	*Scirpus robustus*	*Cyperus odoratus*	*Acnida alabamensis*	*Ptilimnium nuttallii*	*Eleocharis sp.*	*Eleocharis obtusa*	*Polygonum sp. A*	*Panicum virgatum*
0.0	7.6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6	15.2	1	0	0	0	1	0	0	0	0	0	0	0	0	0
15.2	22.9	0	3	0	0	3	0	0	0	0	0	0	0	0	0
22.9	30.5	0	3	0	0	5	0	0	0	0	0	0	0	0	0
30.5	38.1	0	1	0	0	5	0	0	0	0	0	0	0	0	0
38.1	45.7	0	1	0	0	3	0	0	0	0	0	0	0	0	0
45.7	53.3	0	0	0	0	0	0	0	3	0	0	0	0	0	0
53.3	61.0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
61.0	68.6	0	0	0	0	0	0	0	5	0	0	0	0	0	0
68.6	76.2	0	0	0	0	0	0	0	5	0	0	0	0	0	0
76.2	83.8	0	0	0	0	0	0	0	4	0	3	0	0	0	0
83.8	91.4	0	0	0	0	0	0	0	5	0	2	0	0	0	0
91.4	99.1	0	0	0	0	0	0	0	3	0	0	0	0	0	0
99.1	106.7	0	0	0	0	0	0	0	5	0	0	0	0	0	0
106.7	114.3	0	0	0	0	0	0	0	5	0	0	3	0	0	0
114.3	121.9	0	0	0	0	0	0	0	2	0	0	0	0	0	0
121.9	129.5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
129.5	137.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
137.2	144.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SM08 (contd.)

Depth Interval cm		Myriophyllum spicatum	Cladium jamaicense	Scirpus californicus	Jussiaea sp.	Najas quadalupensis	Sagittaria falcata	Potamogeton pusillus	Centella asiatica	Carex sp.	Panicum hemitomon	Hypericum sp.	Zizaniopsis miliacea	Sagittaria falcata	Polygonum sp. B
0.0	7.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.2	22.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.9	30.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30.5	38.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38.1	45.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45.7	53.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53.3	61.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61.0	68.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68.6	76.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76.2	83.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83.8	91.4	0	3	0	0	0	0	0	0	0	0	0	0	0	0
91.4	99.1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
99.1	106.7	0	0	0	1	3	0	0	0	0	0	0	0	0	0
106.7	114.3	0	1	1	1	0	0	0	0	1	0	0	0	0	0
114.3	121.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0
121.9	129.5	0	0	0	0	0	0	0	1	1	0	0	0	1	0
129.5	137.2	0	0	0	0	0	0	0	1	0	0	0	0	2	0
137.2	144.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX IV SEEDS CORE SM08 (contd.)

Depth Interval cm		Utricularia sp.	Zannichellia palustris	Eichornia crassipes	Sagittaria platyphylla	Cyperus erythrorhizos	Hydrocotyle umbellata	Panicum sp.	Dulichium sp.	Panicum agrostoides	Incertae sedis A	Incertae sedis B	fish scales
0.0	7.6	0	0	0	0	0	0	0	0	0	0	0	0
7.6	15.2	0	0	0	0	0	0	0	0	0	0	0	0
15.2	22.9	0	0	0	0	0	0	0	0	0	0	0	0
22.9	30.5	0	0	0	0	0	0	0	0	0	0	0	0
30.5	38.1	0	0	0	0	0	0	0	0	0	0	0	0
38.1	45.7	0	0	0	0	0	0	0	0	0	0	0	0
45.7	53.3	0	0	0	0	0	0	0	0	0	0	0	0
53.3	61.0	0	0	0	0	0	0	0	0	0	0	0	0
61.0	68.6	0	0	0	0	0	0	0	0	0	0	0	0
68.6	76.2	0	0	0	0	0	0	0	0	0	0	0	0
76.2	83.8	0	0	0	0	0	0	0	0	0	0	0	0
83.8	91.4	0	0	0	0	0	0	0	0	0	0	0	0
91.4	99.1	0	0	0	0	0	0	0	0	0	0	0	0
99.1	106.7	0	0	0	0	1	1	0	0	0	0	0	0
106.7	114.3	0	0	0	0	0	0	0	0	0	0	0	0
114.3	121.9	0	0	0	0	0	0	0	0	0	0	0	0
121.9	129.5	0	0	0	0	0	0	0	0	0	0	0	0
129.5	137.2	0	0	0	0	0	0	0	0	0	0	0	0
137.2	144.8	0	0	0	0	0	0	0	0	0	0	0	0

0=ABSENT 1=RARE 2=RARE TO COMMON 3=COMMON 4=COMMON TO ABUNDANT 5=ABUNDANT 6=VERY ABUNDANT

APPENDIX V

FORAMINIFERA CORE SWLA4

(absolute counts)

DEPTH INTERVAL cm		Trochammina inflata	Haplophragmoides sp.	Jadammina polystoma	Arenoparella mexicana	Trochammina macrescens		Tiphotrocha comprimata
						*	**	
0	7.6	10	0	10	11	2	0	8
7.6	15.2	8	0	9	4	3	0	1
15.2	22.9	6	0	3	13	6	3	9
22.9	30.5	5	0	8	4	12	20	10
30.5	38.1	9	2	0	33	4	6	13
38.1	45.7	22	3	0	97	8	13	80
47.0	54.6	15	0	0	83	13	25	51
54.6	62.2	9	0	0	49	10	40	31
62.2	9.9	5	0	0	43	4	11	20
69.9	77.5	0	0	0	0	0	30	0
77.5	85.1	0	0	0	0	0	18	0

* agglutinated ** pseudo-chitonous

APPENDIX V

FORAMINIFERA CORE SWLA4 contd.

(absolute counts)

DEPTH INTERVAL cm		Recurvoides sp.	Milliamina fusca	Ammostuata inepta	Elphidium spp.	Ammonia spp.	Ammotium salsum
0	7.6	0	10	14	0	0	0
7.6	15.2	0	0	19	0	0	0
15.2	22.9	0	0	0	0	0	0
22.9	30.5	0	0	13	8	0	0
30.5	38.1	0	0	21	6	0	0
38.1	45.7	2	2	17	0	0	0
47.0	54.6	0	4	43	0	0	0
54.6	62.2	2	0	37	0	0	0
62.2	9.9	5	0	9	0	0	0
69.9	77.5	0	0	0	0	0	0
77.5	85.1	0	0	0	0	0	0

APPENDIX V

FORAMINIFERA CORE SWLA3
(absolute counts)

DEPTH INTERVAL cm		Trochammina inflata	Haplophragmoides sp.	Jadammina polystoma	Arenoparella mexicana	Trochammina macrescens	Tiphotrocha comprimata
0	7.6	5	0	0	27	0	1
7.6	15.2	13	0	0	0	2	0
15.2	22.9	10	0	0	16	6	4
22.9	30.5	5	0	0	28	4	0
30.5	38.1	10	8	5	20	0	4
38.1	45.7	12	4	0	20	0	1
45.7	53.3	15	2	0	28	10	12
53.3	61.0	8	4	0	15	15	4
61.0	68.6	6	0	0	25	6	22
68.6	76.2	10	1	0	32	4	90
76.2	83.8	3	0	0	31	8	30
86.4	94.0	1	0	0	15	15	1

APPENDIX V

FORAMINIFERA CORE SWLA3 contd.
(absolute counts)

DEPTH INTERVAL cm		*Recurvoides* sp.	*Milliamina fusca*	*Ammostuata inepta*	*Elphidium* spp.	*Ammonia* spp.	*Ammotium salsum*
0	7.6	0	10	0	0	0	0
7.6	15.2	0	28	0	0	0	0
15.2	22.9	0	14	2	3	0	0
22.9	30.5	6	0	15	60	70	20
30.5	38.1	0	5	5	110	48	25
38.1	45.7	0	0	5	45	29	15
45.7	53.3	0	6	16	36	10	1
53.3	61.0	0	3	8	25	14	20
61.0	68.6	2	0	8	50	15	10
68.6	76.2	0	0	10	5	0	20
76.2	83.8	0	0	54	0	0	0
86.4	94.0	0	1	25	0	0	2

APPENDIX V

FORAMINIFERA CORE SM08
(absolute counts)

DEPTH INTERVAL cm		Trochammina inflata	Haplophragmoides sp.	Jadammina polystoma	Arenoparella mexicana	Trochammina macrescens	Tiphotrocha comprimata
0	7.6	13	13	0	7	0	3
7.6	15.2	30	15	0	19	2	5
15.2	22.9	6	5	0	0	34	4
22.9	30.5	0	26	0	3	27	5
30.5	38.1	0	9	0	2	20	4
38.1	45.7	0	34	0	1	3	1
45.7	53.3	1	15	0	0	31	7
53.3	61.0	0	1	0	0	27	0
61.0	68.6	0	0	0	0	20	0
68.6	76.2	0	0	0	0	15	0

APPENDIX V

FORAMINIFERA CORE SM08 contd.
(absolute counts)

DEPTH INTERVAL cm		Recurvoides sp.	Milliamina fusca	Ammostuete inepta	Elphidium spp.	Ammonia spp.	Ammotium salsum
0	7.6	1	0	0	0	0	0
7.6	15.2	0	0	12	0	0	0
15.2	22.9	0	0	0	0	0	0
22.9	30.5	2	1	7	0	0	0
30.5	38.1	5	0	0	0	0	0
38.1	45.7	124	0	1	0	0	0
45.7	53.3	55	0	4	0	0	0
53.3	61.0	15	0	0	0	0	0
61.0	68.6	8	0	0	0	0	0
68.6	76.2	0	0	0	0	0	0

APPENDIX VI. GEMMULE DATA

APPENDIX VI

GEMMULES CORE SWLA4 (absolute counts)

DEPTH INTERVAL cm		Spongillia lacustris	Ephydatia fluviatalis	Heteromeyenia baileyi	Anheteromeyenia argyrosperma	Dosillia radiospiculata	Radiospongillia crateriformis	Anheteromeyenia ryderi
62.2	69.9	10	0	0	0	0	0	0
69.9	77.5	0	10	0	0	0	0	0
77.5	85.1	0	10	0	0	0	0	0
85.1	92.7	0	0	0	0	0	0	0
96.5	105.4	0	0	0	0	0	0	0
105.4	113.0	0	7	0	0	3	0	0
113.0	120.7	0	6	6	0	3	0	3
120.7	128.3	0	0	3	0	3	0	3
128.3	135.9	0	0	0	0	6	0	3
135.9	143.5	0	0	5	0	5	0	0
143.5	151.1	0	16	0	0	13	0	3
151.1	158.8	0	5	0	0	44	0	5

APPENDIX VI

GEMMULES CORE SWLA4 contd. (absolute counts)

DEPTH INTERVAL cm		Spongillia lacustris	Ephydatia fluviatalis	Heteromeyenia baileyi	Anheteromeyenia argyrosperma	Dosillia radiospiculata	Radiospongillia crateriformis	Anheteromeyenia ryderi
158.8	166.4	0	10	0	0	26	0	0
166.4	174.0	0	5	0	0	19	0	0
174.0	184.2	0	12	0	0	12	0	8
184.2	191.8	0	0	0	0	0	0	0
191.8	199.4	0	4	0	0	2	0	0
199.4	203.2	0	2	0	0	5	0	2
203.2	210.8	0	0	0	0	0	0	0
210.8	218.4	0	0	0	0	5	0	5
218.4	226.1	0	0	0	0	10	0	0
226.1	233.7	0	0	3	0	6	0	0
233.7	241.3	0	0	0	0	2	0	0

APPENDIX VI

GEMMULES CORE SWLA3 (absolute counts)

DEPTH INTERVAL cm		Spongillia lacustris	Ephydatia fluviatalis	Heteromeyenia baileyi	Anheteromeyenia argyrosperma	Dosillia radiospiculata	Radiospongillia crateriformis	Anheteromeyenia ryderi
118.8	119.4	0	10	0	0	0	0	0
119.4	127.0	0	0	18	0	0	0	0
127.0	134.6	0	0	20	0	0	0	0
134.6	142.2	0	3	10	13	0	0	0
142.2	147.3	0	0	0	0	0	0	0
147.3	152.4	0	9	18	9	0	0	0
152.4	157.5	0	0	3	0	0	0	27
157.5	166.4	0	0	6	0	0	15	9
166.4	175.3	0	0	0	0	0	25	0

APPENDIX VI

GEMMULES CORE SM08 (absolute counts)

DEPTH INTERVAL cm		Spongillia lacustris	Ephydatia fluviatalis	Heteromeyenia baileyi	Anheteromeyenia argyrosperma	Dosillia radiospiculata	Radiospongillia crateriformis	Anheteromeyenia ryderi
68.6	76.2	0	10	0	0	0	0	0
76.2	83.8	0	10	0	0	0	0	0
83.8	91.4	0	11	11	0	0	0	0
91.4	99.1	0	16	4	0	0	0	0
99.1	106.7	0	16	4	0	0	0	0
106.7	114.3	0	34	0	0	0	0	0
114.3	121.9	0	15	15	0	0	0	0
121.9	129.5	0	0	24	0	0	0	0
129.5	137.2	0	0	24	0	0	0	0

APPENDIX VII. MACERAL ANALYSIS DATA

APPENDIX VII

MACERAL ANALYSIS CORE SWLA4

PHYTOCLASTS

DEPTH INTERVAL cm		WELL PRES.		POORLY PRES.		INFEST.		AMOR. STR.		AMOR. UNSTR.		AMOR. INF.	
		*	**										
0	7.6	6.5	(2)	19.4	(12)	21.0	(13)	3.2	(2)	6.5	(4)	11.3	(7)
7.6	15.2	3.4	(0)	16.9	(10)	25.4	(15)	3.4	(2)	5.1	(3)	15.3	(9)
22.9	30.5	8.3	(5)	16.7	(10)	16.7	(10)	11.7	(7)	16.7	(10)	18.3	(11)
38.1	45.7	9.7	(6)	4.8	(3)	11.3	(7)	4.8	(3)	14.5	(9)	32.3	(20)
54.6	62.2	10.2	(6)	6.8	(4)	11.9	(7)	6.8	(4)	13.6	(8)	30.5	(18)
69.9	77.5	8.5	(5)	5.1	(3)	10.2	(6)	3.4	(2)	47.5	(28)	15.3	(9)
85.1	92.7	5.0	(3)	3.3	(2)	15.0	(9)	6.7	(4)	23.3	(14)	30.0	(18)
105.4	113.0	4.5	(3)	3.0	(2)	12.1	(8)	4.5	(3)	34.8	(23)	33.3	(22)
120.7	128.3	4.6	(3)	15.4	(10)	4.6	(3)	7.7	(5)	30.8	(20)	30.8	(20)
135.9	143.5	0.0	(0)	16.7	(11)	7.6	(5)	10.6	(7)	30.3	(20)	21.2	(14)
151.1	158.8	4.7	(3)	18.8	(12)	6.3	(4)	3.1	(2)	32.8	(21)	28.1	(18)

* RELATIVE PERCENT ** TOTAL COUNT

APPENDIX VII

MACERAL ANALYSIS CORE SWLA4 (contd.)

PHYTOCLASTS

DEPTH INTERVAL cm		WELL PRES.		POORLY PRES.		INFEST.		AMOR. STR.		AMOR. UNSTR.		AMOR. INF.	
		*	**										
166.4	174.0	0.0	(0)	16.2	(11)	2.9	(2)	4.4	(3)	26.5	(18)	35.3	(24)
184.2	191.8	0.0	(0)	13.6	(9)	6.1	(4)	6.1	(4)	28.8	(19)	27.3	(18)
199.4	203.2	0.0	(0)	4.5	(3)	6.1	(4)	7.6	(5)	16.7	(11)	40.9	(27)
210.8	218.4	0.0	(0)	11.7	(7)	3.3	(2)	16.7	(10)	20.0	(12)	16.7	(10)
226.1	233.7	1.5	(1)	13.8	(9)	9.2	(6)	6.2	(4)	16.9	(11)	18.5	(12)
241.3	248.9	0.0	(0)	6.3	(4)	6.3	(4)	46.9	(30)	9.4	(6)	9.4	(6)
256.6	264.2	11.3	(7)	8.1	(5)	8.1	(5)	30.6	(19)	11.3	(7)	1.6	(1)
273.1	281.9	6.5	(4)	8.1	(5)	6.5	(4)	35.5	(22)	14.5	(9)	9.7	(6)
292.1	301.0	4.5	(3)	3.0	(2)	6.0	(4)	47.8	(32)	9.0	(6)	6.0	(4)

* RELATIVE PERCENT

** TOTAL COUNT

APPENDIX VII

MACERAL ANALYSIS CORE SWLA4

OTHER MACERALS

DEPTH INTERVAL cm		AMOR. INF. INDET.		AMOR. PROT.		SCLERAT.		INERT.		MIOSP.		
		*	**									***
0	7.6	27.4	(17)	0.0	(0)	3.2	(2)	8.1	(5)	1.6	(1)	2.0
7.6	15.2	20.3	(12)	0.0	(0)	6.8	(4)	10.2	(6)	3.4	(2)	2.0
22.9	30.5	6.7	(4)	0.0	(0)	5.0	(3)	6.7	(4)	0.0	(0)	–
38.1	45.7	14.5	(9)	0.0	(0)	1.6	(1)	12.9	(8)	6.5	(4)	2.3
54.6	62.2	16.9	(10)	0.0	(0)	3.4	(2)	6.8	(4)	0.0	(0)	–
69.9	77.5	5.1	(3)	0.0	(0)	5.1	(3)	8.5	(5)	0.0	(0)	–
85.1	92.7	10.0	(6)	0.0	(0)	5.0	(3)	15.0	(9)	1.7	(1)	2.0
105.4	113.0	3.0	(2)	0.0	(0)	3.0	(2)	3.0	(2)	1.5	(1)	2.0
120.7	128.3	1.5	(1)	0.0	(0)	4.6	(3)	15.4	(1)	0.0	(0)	–
135.9	143.5	10.6	(7)	0.0	(0)	1.5	(1)	3.0	(2)	1.5	(1)	2.0
151.1	158.8	6.3	(4)	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	–

* RELATIVE PERCENT ** TOTAL COUNT *** MIOSPORE COLOR

APPENDIX VII

MACERAL ANALYSIS CORE SWLA4 (contd.)

OTHER MACERALS

DEPTH INTERVAL cm		AMOR. INF. INDET.		AMOR. PROT.		SCLERAT.		INERT.		MIOSP.		
		*	**									***
166.4	174.0	10.3	(7)	0.0	(0)	1.5	(1)	1.5	(1)	2.9	(2)	2.0
184.2	191.8	16.7	(11)	0.0	(0)	0.0	(0)	1.5	(1)	1.5	(1)	2.0
199.4	203.2	12.1	(8)	10.6	(7)	0.0	(0)	0.0	(0)	1.5	(1)	2.0
210.8	218.4	11.7	(7)	16.7	(10)	1.7	(1)	10.0	(6)	1.7	(1)	2.0
226.1	233.7	10.8	7)	12.3	(8)	9.2	(6)	3.1	(2)	1.5	(1)	2.0
241.3	248.9	0.0	(0)	14.1	(9)	6.3	(4)	43.8	(28)	1.6	(1)	4.0
256.6	264.2	0.0	(0)	8.1	(5)	12.9	(8)	29.0	(18)	8.0	(5)	4.8
273.1	281.9	4.8	(3)	6.5	(4)	6.5	(4)	35.5	(22)	1.6	(1)	4.0
292.1	301.0	0.0	(0)	11.9	(8)	9.0	(6)	40.3	(27)	3.0	(2)	2.5

* RELATIVE PERCENT ** TOTAL COUNT *** MIOSPORE COLOR

APPENDIX VII

MACERAL ANALYSIS CORE SWLA3

PHYTOCLASTS

DEPTH INTERVAL cm		WELL PRES.		POORLY PRES.		INFEST.		AMOR. STR.		AMOR. UNSTR.		AMOR. INF.	
		*	**										
0	7.6	1.7	(1)	23.3	(14)	25.0	(15)	11.7	(7)	3.3	(2)	8.3	(5)
7.6	15.2	4.8	(3)	12.7	(8)	14.3	(9)	11.1	(7)	3.2	(2)	14.3	(9)
22.9	30.5	5.0	(3)	5.0	(3)	15.0	(9)	18.3	(11)	8.3	(5)	23.3	(14)
38.1	45.7	11.1	(7)	7.9	(5)	6.3	(4)	6.3	(4)	6.3	(4)	31.7	(20)
53.3	61.0	6.5	(4)	9.7	(6)	9.7	(6)	12.9	(8)	9.7	(6)	14.5	(9)
68.6	76.2	4.7	(3)	7.8	(5)	7.8	(5)	7.8	(5)	1.6	(1)	17.2	(11)
76.2	83.8	3.3	(2)	3.3	(2)	11.7	(7)	15.0	(9)	3.3	(2)	21.7	(13)
86.4	94.0	3.3	(2)	3.3	(0)	11.7	(6)	15.0	(7)	3.3	(3)	23.3	(14)
101.6	104.1	0.0	(0)	4.9	(3)	4.9	(3)	8.2	(5)	6.6	(4)	13.1	(8)
111.8	119.4	3.3	(2)	10.0	(6)	15.0	(9)	8.3	(5)	13.3	(8)	36.7	(22)
127.0	134.6	1.6	(1)	4.9	(3)	14.8	(9)	11.5	(7)	13.1	(8)	44.3	(27)
142.2	147.3	0.0	(0)	5.0	(3)	16.7	(10)	15.0	(9)	13.3	(8)	40.0	(24)
152.4	157.5	1.6	(1)	6.6	(4)	6.6	(4)	11.5	(7)	18.0	(11)	9.8	(6)
166.4	175.3	1.7	(1)	3.3	(2)	8.3	(5)	16.7	(10)	11.7	(7)	13.3	(8)

* RELATIVE PERCENT ** TOTAL COUNT

APPENDIX VII

MACERAL ANALYSIS CORE SWLA3

OTHER MACERALS

DEPTH INTERVAL cm		AMOR. INF. INDET.		AMOR. PROT.		SCLERAT.		INERT.		MIOSP.		
		*	**									***
0	7.6	18.3	(11)	0.0	(0)	3.3	(2)	5.0	(3)	5.0	(3)	2.0
7.6	15.2	9.5	(6)	7.9	(5)	17.5	(11)	1.6	(10)	4.8	(3)	3.3
22.9	30.5	5.0	(3)	5.0	(3)	15.0	(9)	13.3	(8)	0.0	(0)	–
38.1	45.7	4.8	(3)	11.1	(7)	9.5	(6)	7.9	(5)	4.8	(3)	3.0
53.3	61.0	11.3	(7)	9.7	(6)	12.9	(8)	12.9	(8)	3.2	(2)	3.0
68.6	76.2	15.6	(10)	14.1	(9)	18.8	(12)	14.1	(9)	4.7	(3)	2.0
76.2	83.8	25.0	(15)	8.3	(5)	8.3	(5)	13.3	(8)	0.0	(0)	–
86.4	94.0	23.3	(16)	5.0	(3)	15.0	(9)	5.0	(3)	0.0	(0)	–
101.6	104.1	21.3	(13)	8.2	(5)	21.3	(13)	0.0	(0)	11.5	(7)	2.6
111.8	119.4	8.3	(5)	0.0	(0)	3.3	(2)	0.0	(0)	0.0	(0)	–
127.0	134.6	8.2	(5)	0.0	(0)	1.7	(1)	0.0	(0)	0.0	(0)	–
142.2	147.3	8.3	(5)	0.0	(0)	1.7	(1)	3.3	(2)	0.0	(0)	–
152.4	157.5	18.0	(11)	11.5	(7)	14.8	(9)	3.3	(2)	1.6	(1)	6.0
166.4	175.3	16.7	(10)	10.0	(6)	18.3	(2)	0.0	(0)	0.0	(0)	–

* RELATIVE PERCENT ** TOTAL COUNT *** MIOSPORE COLOR

APPENDIX VII

MACERAL ANALYSIS CORE SM08

PHYTOCLASTS

DEPTH INTERVAL cm		WELL PRES.		POORLY PRES.		INFEST.		AMOR. STR.		AMOR. UNSTR.		AMOR. INF.	
		*	**										
0	7.6	6.9	(4)	20.7	(12)	22.4	(13)	5.2	(3)	0.0	(0)	10.3	(6)
7.6	15.2	3.5	(2)	22.4	(13)	24.1	(14)	13.8	(8)	0.0	(0)	12.1	(7)
22.9	30.5	1.7	(1)	8.3	(5)	16.7	(10)	6.7	(4)	18.3	(11)	23.3	(14)
38.1	45.7	0.0	(0)	10.0	(6)	20.0	(12)	10.0	(6)	10.0	(6)	30.0	(18)
53.3	61.0	6.5	(4)	8.1	(5)	16.1	(10)	12.9	(8)	4.8	(3)	30.6	(19)
68.6	76.2	5.0	(3)	10.0	(6)	8.3	(5)	5.0	(3)	18.3	(11)	26.7	(16)
83.8	91.4	4.8	(3)	11.3	(7)	9.7	(6)	12.9	(8)	22.6	(14)	25.8	(16)
99.1	106.7	5.0	(3)	10.0	(6)	10.0	(6)	15.0	(9)	16.7	(10)	31.7	(19)
106.7	114.3	3.4	(2)	10.2	(6)	13.6	(8)	10.2	(6)	20.3	(12)	30.5	(18)
121.9	129.5	8.8	(6)	22.1	(15)	8.8	(6)	14.7	(10)	13.2	(9)	17.6	(12)
129.5	137.2	4.4	(3)	14.7	(10)	7.4	(5)	10.3	(7)	14.7	(10)	23.5	(16)

* RELATIVE PERCENT

** TOTAL COUNT

APPENDIX VII

MACERAL ANALYSIS CORE SM08

OTHER MACERALS

DEPTH INTERVAL cm		AMOR. INF. INDET.		AMOR. PROT.		SCLERAT.		INERT.		MIOSP.		
		*	**									***
0	7.6	29.3	(17)	0.0	(0)	1.7	(1)	0.0	(0)	3.4	(2)	2.0
7.6	15.2	20.7	(12)	0.0	(0)	0.0	(0)	0.0	(0)	3.4	(2)	2.0
22.9	30.5	23.3	(14)	0.0	(0)	0.0	(0)	0.0	(0)	1.7	(1)	4.0
38.1	45.7	15.0	(9)	0.0	(0)	5.0	(3)	3.3	(2)	0.0	(0)	–
53.3	61.0	17.7	(11)	0.0	(0)	1.6	(1)	3.2	(2)	1.6	(1)	2.0
68.6	76.2	23.3	(14)	0.0	(0)	0.0	(0)	15.0	(9)	3.3	(2)	2.5
83.8	91.4	11.3	(7)	0.0	(0)	0.0	(0)	14.5	(9)	1.6	(1)	2.0
99.1	106.7	11.7	(7)	0.0	(0)	0.0	(0)	11.7	(7)	0.0	(0)	–
106.7	114.3	11.9	(7)	0.0	(0)	0.0	(0)	6.8	(4)	0.0	(0)	–
121.9	129.5	13.2	(9)	0.0	(0)	1.5	(1)	11.8	(8)	0.0	(0)	–
129.5	137.2	23.5	(16)	0.0	(0)	1.5	(1)	11.8	(8)	0.0	(0)	–

* RELATIVE PERCENT ** TOTAL COUNT *** MIOSPORE COLOR

APPENDIX VIII. TOTAL ORGANIC CARBON DATA

APPENDIX VIII

TOTAL ORGANIC CARBON

CORE SWLA4

INTERVAL CM

UPPER DEPTH	LOWER DEPTH	TOC
0	7.6	11.58
7.6	15.2	11.65
15.2	22.9	9.07
22.9	30.5	11.06
30.5	38.1	6.76
38.1	45.7	12.48
47.0	54.6	17.09
54.6	62.2	11.46
62.2	69.9	16.56
69.9	77.5	15.77
77.5	85.1	13.49
85.1	92.7	12.19
96.5	105.4	31.25
105.4	113.0	28.14
113.0	120.7	27.66
120.7	128.3	27.93
128.3	135.9	29.68
135.9	143.5	29.49
143.5	151.1	25.79
151.1	158.8	25.92

APPENDIX VIII

TOTAL ORGANIC CARBON

CORE SWLA4 (contd.)

INTERVAL CM

UPPER DEPTH	LOWER DEPTH	TOC
158.8	166.4	23.84
166.4	174.0	22.41
174.0	184.2	19.74
184.2	191.8	16.83
191.8	199.4	12.86
199.4	203.2	10.29
203.2	210.8	8.16
210.8	218.4	4.95
218.4	226.1	3.68
226.1	233.7	3.66
233.7	241.3	1.17
241.3	248.9	.56
248.9	256.6	.88
256.6	264.2	.74
264.2	273.1	.30
273.1	281.9	.90
281.8	292.1	.94
292.1	301.0	.98

APPENDIX VIII

TOTAL ORGANIC CARBON

CORE SWLA3

INTERVAL CM

UPPER DEPTH	LOWER DEPTH	TOC
0	7.6	16.96
7.6	15.2	6.89
15.2	22.9	5.33
22.9	30.5	3.65
30.5	38.1	3.45
38.1	45.7	4.21
45.7	53.3	3.20
53.3	61.0	4.85
61.0	68.6	6.57
68.6	76.2	9.67
76.2	83.8	7.67
86.4	94.0	4.94
94.0	101.6	11.07
101.6	104.1	11.38
104.1	111.8	33.49
111.8	119.4	45.83
119.4	127.0	40.31
127.0	134.6	37.51
134.6	142.2	31.78
142.2	147.3	32.56
147.3	152.4	29.75
152.4	157.5	2.34
157.5	166.4	3.10
166.4	175.3	4.87

APPENDIX VIII

TOTAL ORGANIC CARBON

CORE SM08

INTERVAL CM

UPPER DEPTH	LOWER DEPTH	TOC
0	7.6	12.23
7.6	15.2	22.18
15.2	22.9	26.18
22.9	30.5	28.30
30.5	38.1	29.13
38.1	45.7	22.24
45.7	53.3	15.23
53.3	61.0	18.65
61.0	68.6	24.68
68.6	76.2	22.75
76.2	83.8	37.81
83.8	91.4	38.17
91.4	99.1	38.13
99.1	106.7	39.90
106.7	114.3	34.41
114.3	121.9	18.33
121.9	129.5	22.83
129.5	137.2	19.96

VITA

Scott Warren Beckman was born on November 5, 1952 in the Bronx, New York. He graduated from Brooklyn Technical High School in June of 1970. From 1970 to 1974 he attended the State University of New York at Stony Brook where he majored in geology in the Department of Earth and Space Sciences. In 1974 he received a B.S. from the State University of New York at Stony Brook. From 1974 to 1975 he pursued graduate studies in geology at the State University of New York at Stony Brook where he researched the historical development of Long Island marsh deposits. He was awarded a M.S. degree in August of 1975. In 1975 he was employed as a Research Associate in the Sea Grant program at Lousiana State University and worked on the effects of canal building on wetlands in coastal Louisiana. In 1976 he entered the Louisiana State University as a doctoral graduate student in the Department of Marine Sciences. At L.S.U. he directed his studies towards the formation of deltaic peat deposits and lignite geochemistry. From 1979 to 1980 he was employed as a Research Associate at L.S.U. in a Sea Grant program to determine the historical development of coastal Louisiana peat deposits. In 1980 he was employed as a Research Geologist at Phillips Petroleum Company. His research

activities involved developing new visual and geochemical methods for determining source rock potential, lignite petrography of Gulf Coast lignites, and statistical methods in multivariate data analysis. The Louisiana State University awarded him the Ph.D. degree in August of 1985.

Mr. Beckman is presently employed as a Research Geologist at the Phiilips Petroleum Company.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Scott Warren Beckman

Major Field: Marine Sciences

Title of Dissertation: PALEOENVIRONMENTAL RECONSTRUCTIONS AND ORGANIC MATTER CHARACTERIZATIONS OF PEATS AND ASSOCIATED SEDIMENTS FROM CORES IN A PORTION OF THE LAFOURCHE DELTA

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

April 16, 1985